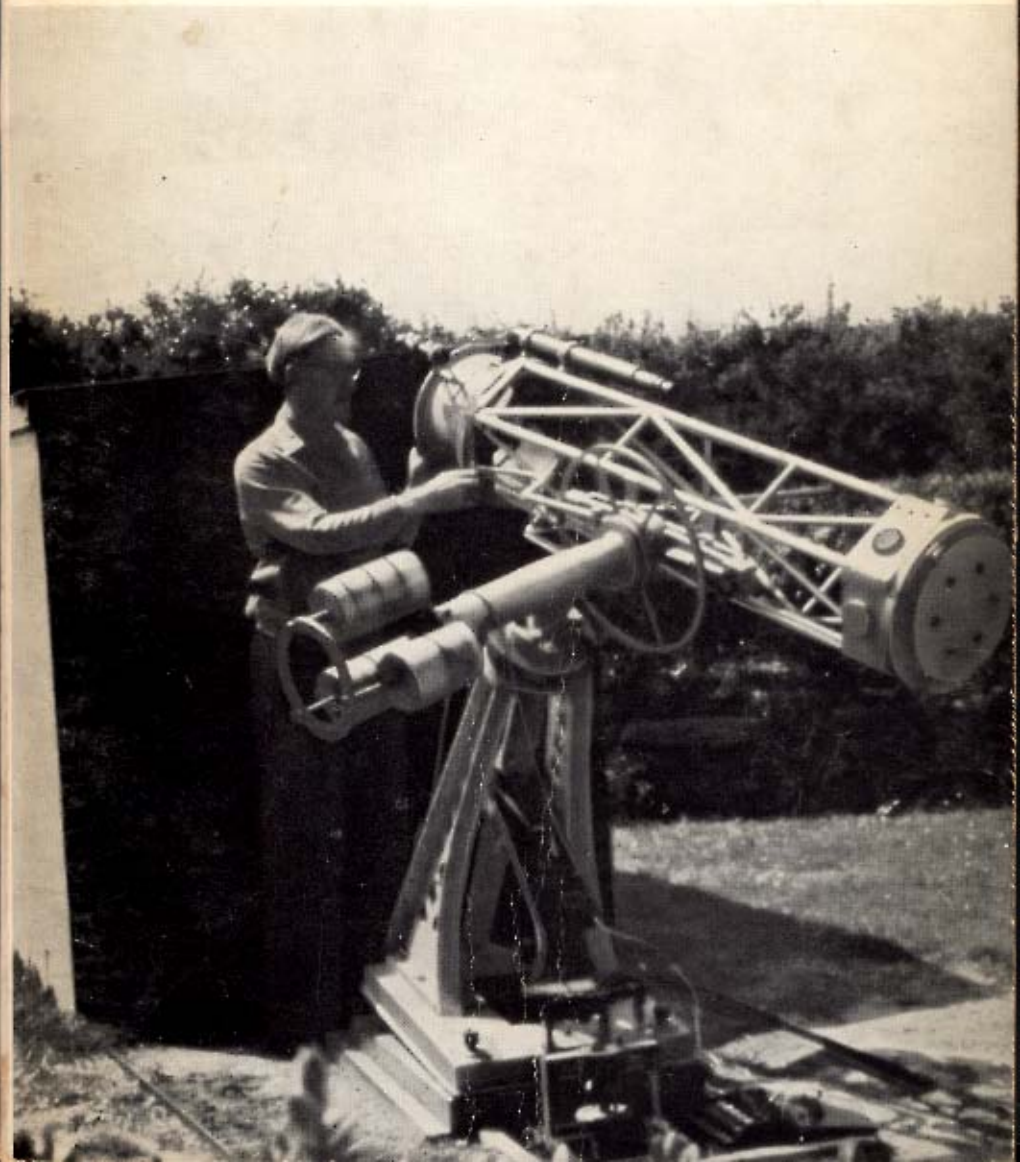
1963 Yearbook of Astronomy

Editor J. G. PORTER

Associate Editor PATRICK MOORE



YEARBOOK OF ASTRONOMY 1963

EDITED BY

J. G. PORTER

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PATRICK MOORE

LONDON

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Preface

The favourable reception given to the first issue of this *Yearbook of Astronomy* has been most encouraging, and shows clearly that there is not only a great deal of interest in astronomy and space research, but also a popular demand for an astronomical publication giving general information on current events. The present issue follows the same lines as its predecessor, but some rearrangement has been made to facilitate the use of the star charts. These have now been brought forward, and are immediately available at the beginning of the book; they are followed by the notes on the planets and other interesting events of each month.

The articles which follow the monthly notes form the greater part of the *Yearbook*, and here it has been the continued aim of the Editors to cover a wide variety of topics, and to give readers the benefit of the experience of both professional and amateur astronomers. In this issue we are pleased to publish a comprehensive account of the various types of eyepieces which are suitable for astronomical telescopes; this has been written by Mr H. E. Dall, who is an acknowledged expert on this subject. The opposition of Mars in 1963 has afforded an opportunity for inviting Professor G. de Vaucouleurs to contribute an account of our present knowledge of this planet, and his authoritative article, with its personal opinions and comments, will be widely appreciated. The shorter articles, dealing with a number of observational and practical matters, will be of interest both to the practising amateur and to the arm-chair astronomer.

New readers will find that all the information is given in descriptive or diagrammatic form; the position of the planets may easily be found on the specially designed star charts, while the monthly notes describe the movements of the planets, and give details of other astronomical phenomena that may be observed

from these latitudes. The reader who needs more detailed information will find *Norton's Star Atlas* invaluable, while more precise positions of the planets and their satellites, together with predictions of occultations, meteor showers and periodic comets, may be found in the *Handbook* of the British Astronomical Association. A somewhat similar publication is the *Observer's Handbook* of the Royal Astronomical Society of Canada, and American readers will also find details of forthcoming events given from time to time in the pages of the monthly *Sky and Telescope*; this magazine also publishes complete details of all occultations visible in North America.

Throughout this volume time is expressed in Greenwich Mean Time; that is, Summer Time is ignored, and the 24-hour clock is used, the day beginning at midnight. The star charts are drawn, and the notes are, in general, designed for use in latitude 52 degrees north, but may be used without alteration throughout the British Isles, and (except in the case of eclipses and occultations) in other countries of similar north latitude.

Notes on the Star Charts

The stars, together with the Sun, Moon and planets, seem to be set on the surface of the celestial sphere, which appears to rotate about the Earth from east to west. Since it is impossible to represent a curved surface accurately on a plane, any kind of star map is bound to contain some form of distortion. But it is well known that the eye can endure some kinds of distortion better than others, and it is particularly true that the eye is most sensitive to deviations from the vertical and horizontal. For this reason the star charts given in this volume on pages 4 to 27 have been designed to give a true representation of vertical and horizontal lines, whatever may be the resulting distortion in the shape of a constellation figure. It will be found that the amount of distortion is, in general, quite small, and is only obvious in the case of large constellations such as Leo and Pegasus, when these appear at the top of the charts, and so are drawn out sideways.

The charts show all stars down to the fourth magnitude, together with a number of fainter stars which are necessary to define the shape of a constellation. There is no standard system for representing the outlines of the constellations, and triangles and other simple figures have been used to give outlines which are easy to follow with the naked eye. The names of the constellations are given, together with the proper names of the brighter stars. The apparent magnitudes of the stars are indicated roughly by using four different sizes of dots, the larger dots representing the brighter stars.

There are four such charts at each opening, and these give a complete coverage of the sky up to an altitude of $62\frac{1}{2}$ degrees; there are twelve such sets to cover the entire year. The upper two charts show the southern sky, south being at the centre; the coverage is 200 degrees in azimuth, from a little north of east

(top left) to a little north of west (top right). The two lower charts show the northern sky, from a little south of west (lower left) to a little south of east (lower right). There is thus an overlap east and west.

The charts have been drawn for a latitude of 52 degrees, but may be taken without appreciable error to appy to all parts of the British Isles. They will also be equally suitable for any other part of the world having a north latitude of about 52 degrees – e.g. parts of Europe and Asia, and Canada. In such cases the times given must be taken as local time, and not G.M.T., which applies only to the British Isles.

Because the sidereal day is shorter than the solar day, the stars appear to rise and set about four minutes earlier each day, which amounts to two hours in a month. Hence the twelve sets of charts are sufficient to give the appearance of the sky throughout the day at intervals of two hours, or at the same time of night at monthly intervals throughout the year. The actual range of dates and times when the stars on the charts are visible is indicated at the top of each page. This information is summarized in the following table, which gives the number of the star chart to be used for any given month and time.

G.M.T.	16^h	18^h	20^h	22^h	0^h	2^h	4^h	6^h
January	10	11	12	1	2	3	4	5
February		12	1	2	3	4	5	6
March			2	3	4	5	6	
April			3	4	5	6		
May			4	5	6	7		
June			5	6	7			
July			6	7	8	9		
August			7	8	9	10	11	
September		7	8	9	10	11	12	
October		8	9	10	11	12	1	
November	8	9	10	11	12	1	2	3
December	9	10	11	12	1	2	3	4

The charts are drawn to scale, and estimates of altitude and azimuth may be made from them. These values will necessarily be mere approximations, since no observer will be exactly on the meridian of Greenwich at 52 degrees latitude, but they will generally serve for the identification of stars and planets. The horizontal measurements, marked at every ten degrees, give the azimuths (or true bearings) measured from the north round through east (90 degrees), south (180 degrees), and west (270 degrees). The vertical measurements, similarly marked, give the altitudes of the stars up to $62\frac{1}{2}$ degrees.

The ecliptic is drawn as a broken line on which the longitude is marked at every ten degrees; the positions of the planets at any time are then easily found by reference to the table immediately following the star charts on page 30.

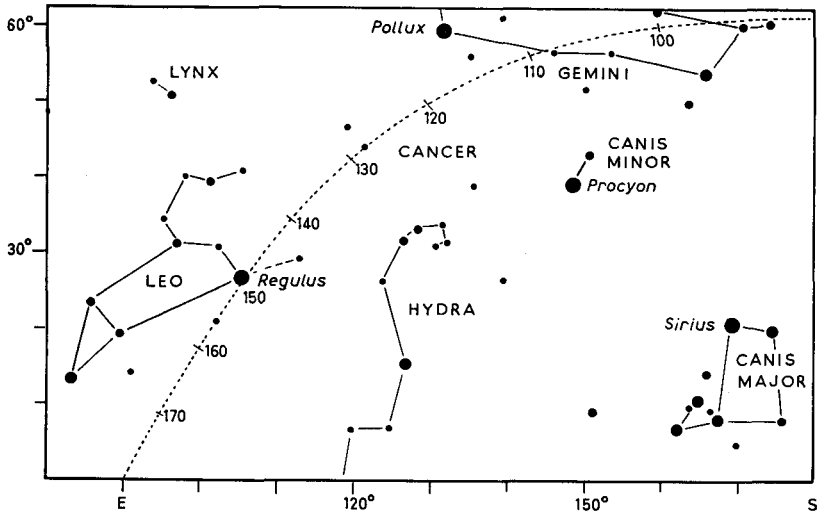
There is a curious illusion that stars at an altitude of 60 degrees or more are actually overhead, and the beginner may often feel that he is leaning over backwards in trying to see them. These high-altitude stars, being nearer the pole, move more slowly across the sky, and a different kind of map may therefore be used. These overhead stars are given separately on pages 28 and 29, the entire year being covered at one opening. Each of the four maps shows the overhead stars at times which correspond to those of three of the main star charts. The position of the zenith in latitude 52 degrees is indicated by a cross, and this cross also marks the centre of a circle which is 35 degrees from the zenith, and which therefore indicates an altitude of 55 degrees; there is thus a small overlap with the main charts.

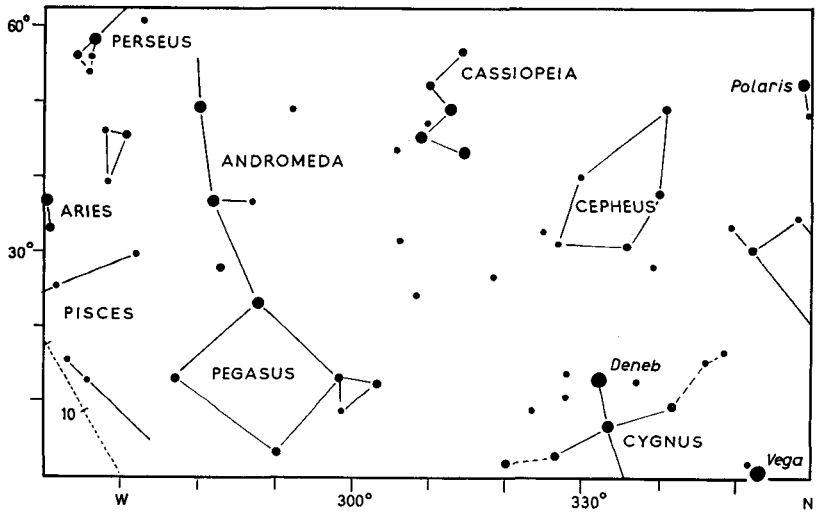
The broken line leading from north to south is numbered to indicate the corresponding main chart. Thus on page 28, the N-S line numbered 6 is to be regarded as an extension of the S line of chart 6 on pages 14 and 15, and at the top of these pages are given dates and times which are appropriate.

The scale is the same on all the charts (approximately 25 degrees to the inch), but the overhead stars are plotted as a true map on a conical projection, and are not simple graphs like the main charts.

1L

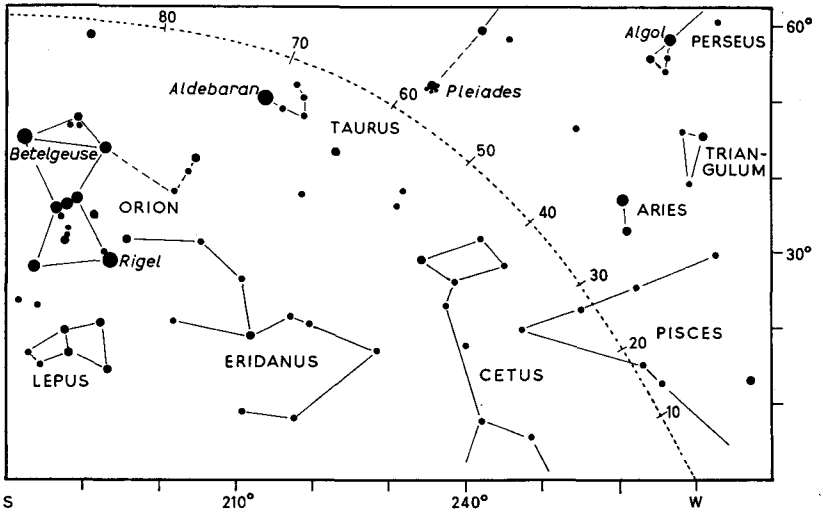
October 6 at	5^h	October 21 at	4^h
November 6 at	3^h	November 21 at	2^h
December 6 at	1^h	December 21 at	midnight
January 6 at	23^h	January 21 at	22^h
February 6 at	21^h	February 21 at	20^h

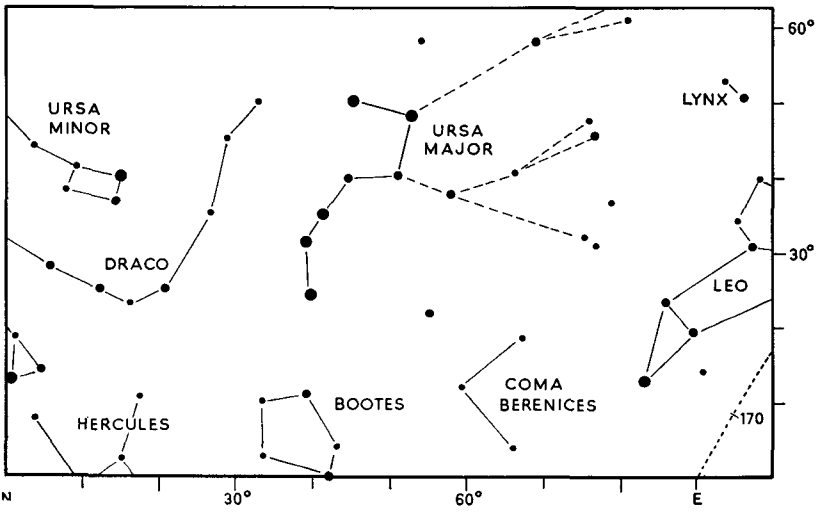




October 6 at	5^h	October 21 at	4^h
November 6 at	3^h	November 21 at	2^h
December 6 at	1^h	December 21 at	midnight
January 6 at	23^h	January 21 at	22^h
February 6 at	21^h	February 21 at	20^h

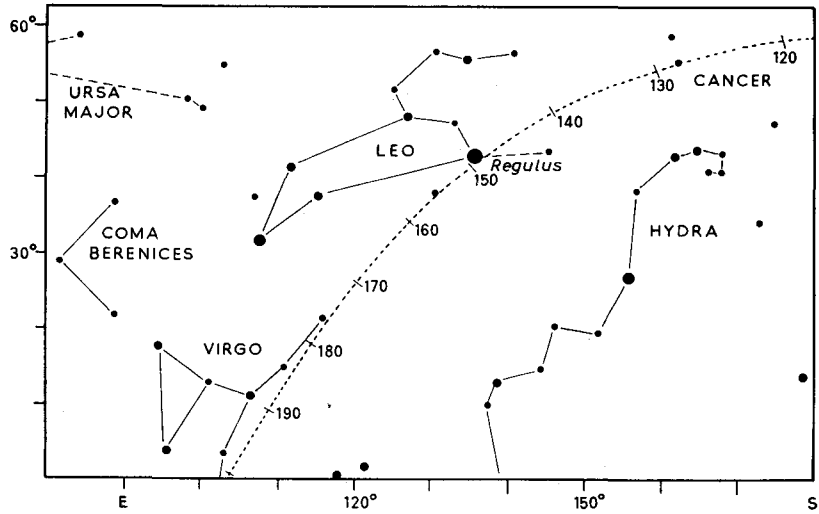
1R

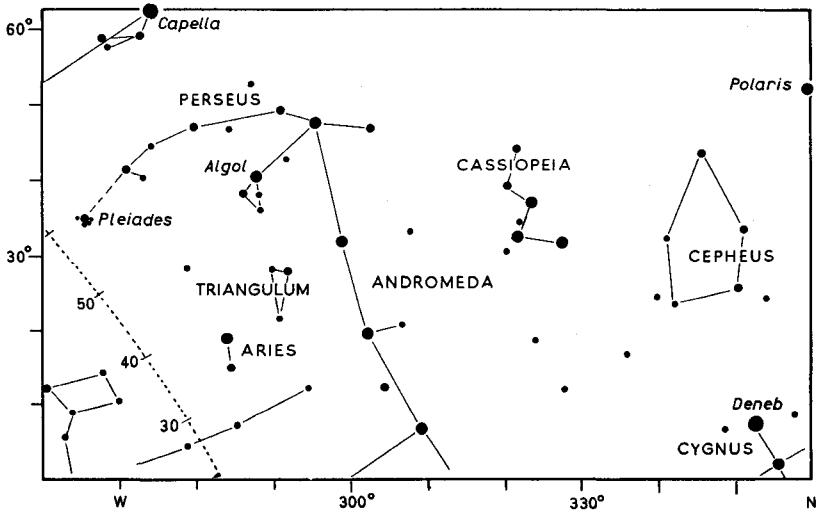




2L

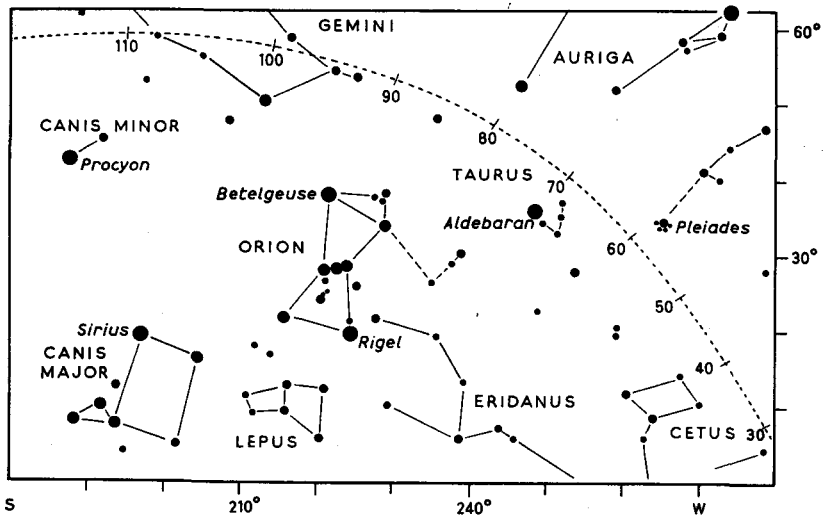
November 6 at 5h	November 21 at 4h
December 6 at 3h	December 21 at 2h
January 6 at 1h	January 21 at midnight
February 6 at 23h	February 21 at 22h
March 6 at 21h	March 21 at 20h

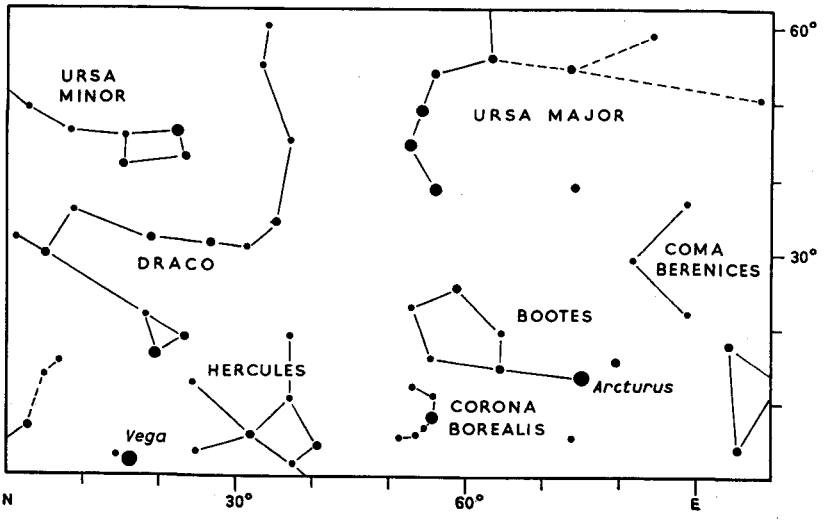




November 6 at	5^h	November 21 at	4^h
December 6 at	3^h	December 21 at	2^h
January 6 at	1^h	January 21 at	midnight
February 6 at	23^h	February 21 at	22^h
March 6 at	21^h	March 21 at	20^h

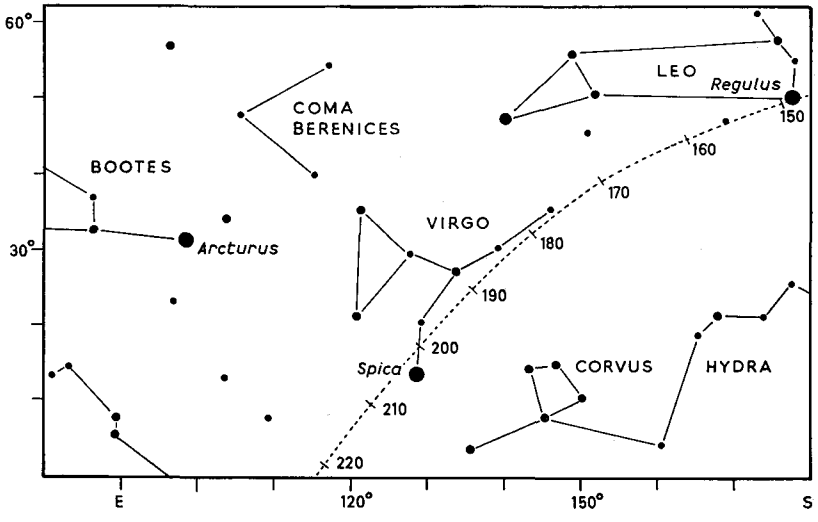
2R

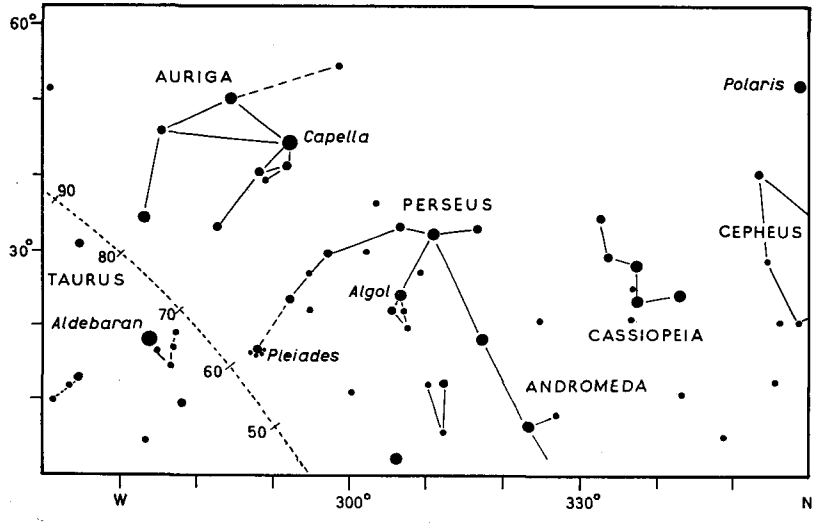




3L

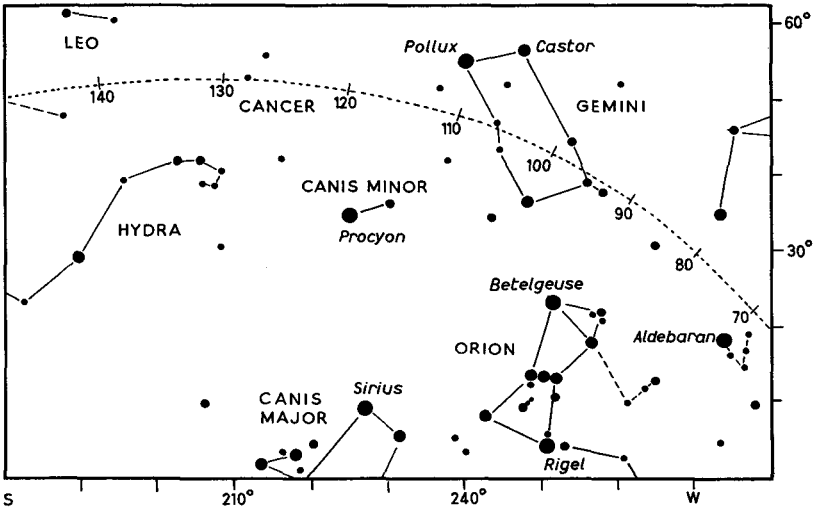
December 6 at	5h	December 21 at	4h
January 6 at	3h	January 21 at	2h
February 6 at	1h	February 21 at	midnight
March 6 at	23h	March 21 at	22h
April 6 at	21h	April 21 at	20h

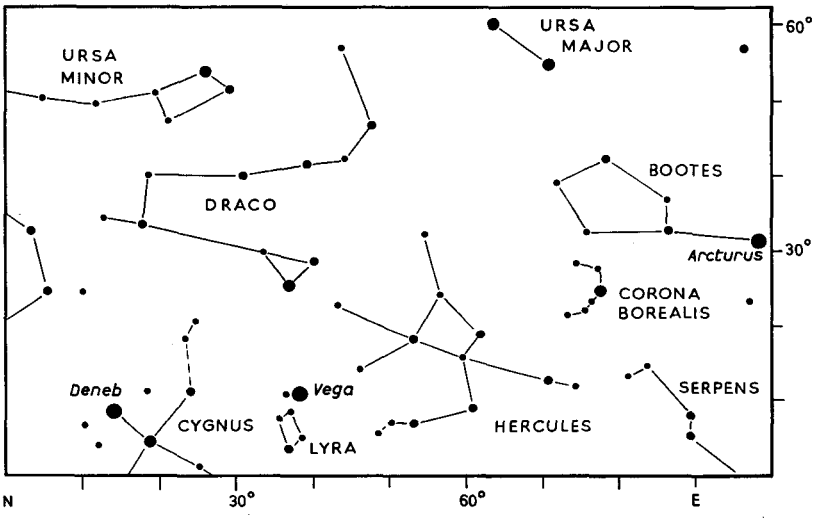




December 6 at 5h	December 21 at 4h
January 6 at 3h	January 21 at 2h
February 6 at 1h	February 21 at midnight
March 6 at 23h	March 21 at 22h
April 6 at 21h	April 21 at 20h

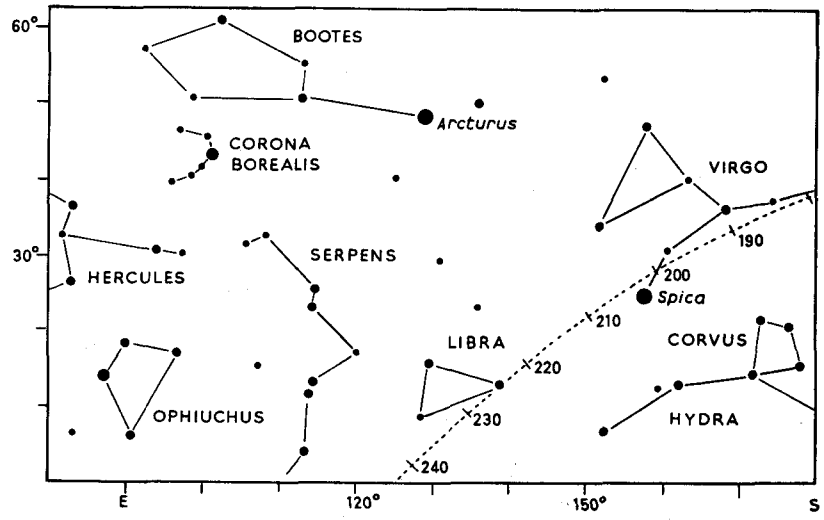
3R

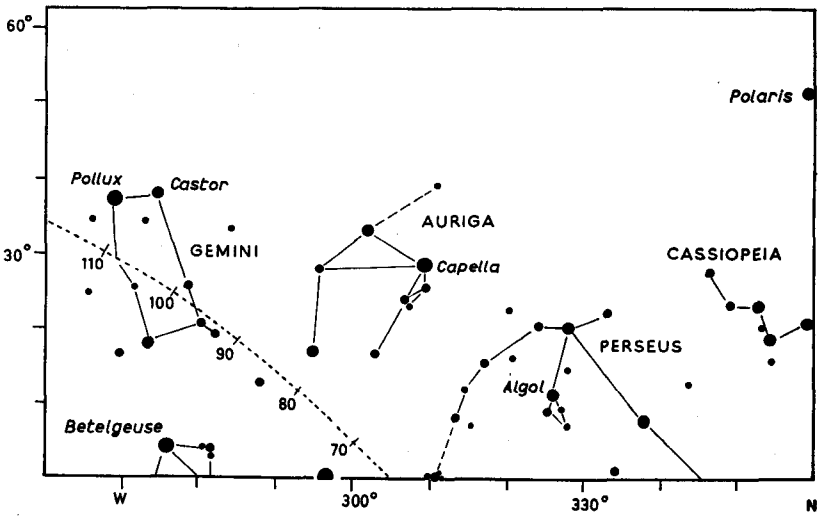




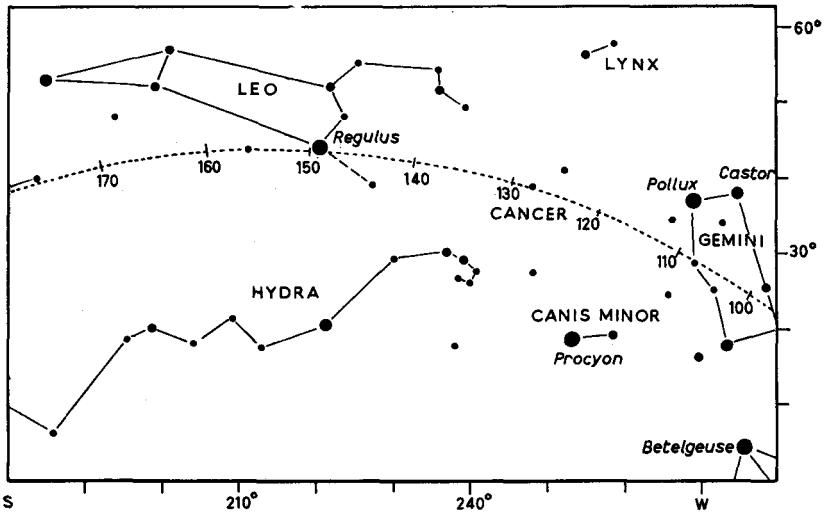
4L

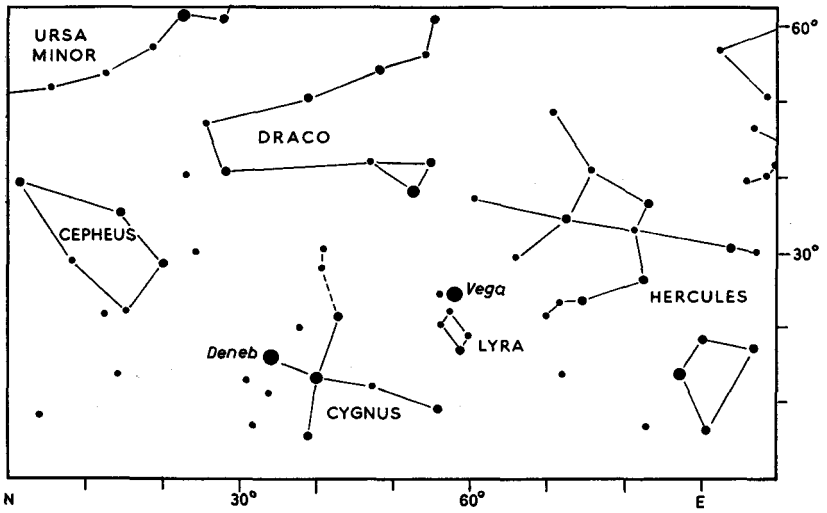
January 6 at	5^h	January 21 at	4^h
February 6 at	3^h	February 21 at	2^h
March 6 at	1^h	March 21 at	midnight
April 6 at	23^h	April 21 at	22^h
May 6 at	21^h	May 21 at	20^h





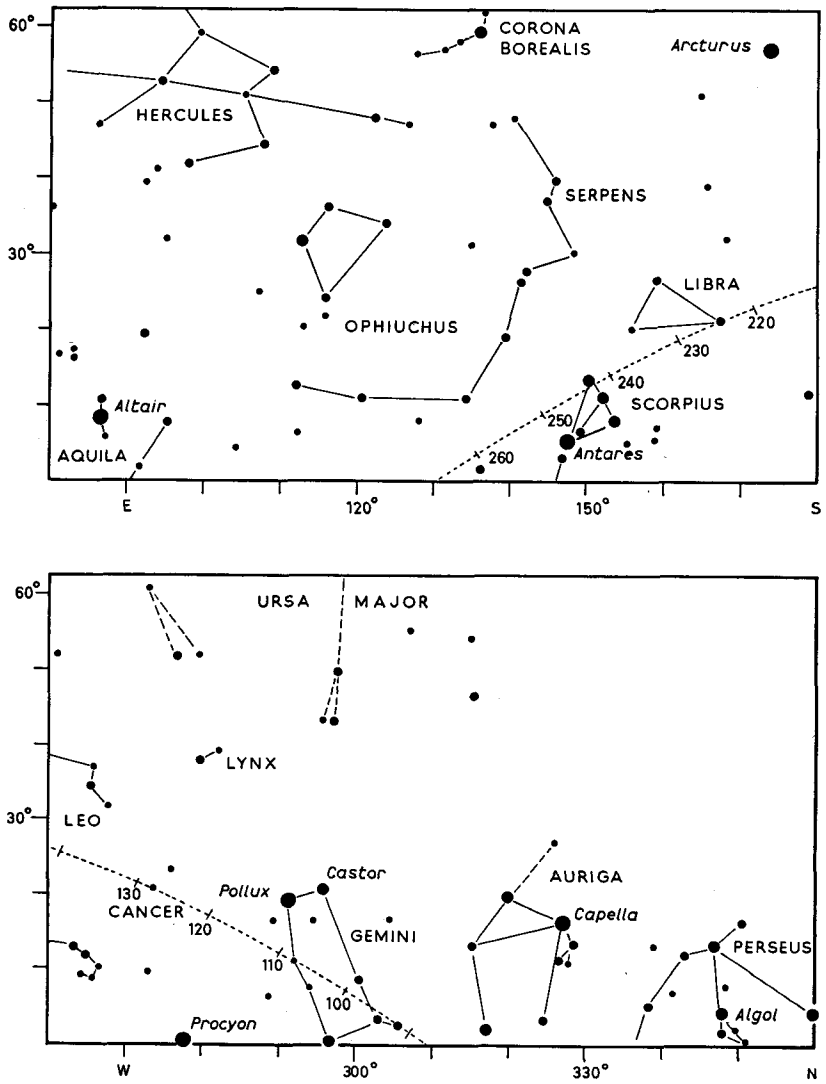
January 6 at 5h	January 21 at 4h	**4R**
February 6 at 3h	February 21 at 2h	
March 6 at 1h	March 21 at midnight	
April 6 at 23h	April 21 at 22h	
May 6 at 21h	May 21 at 20h	



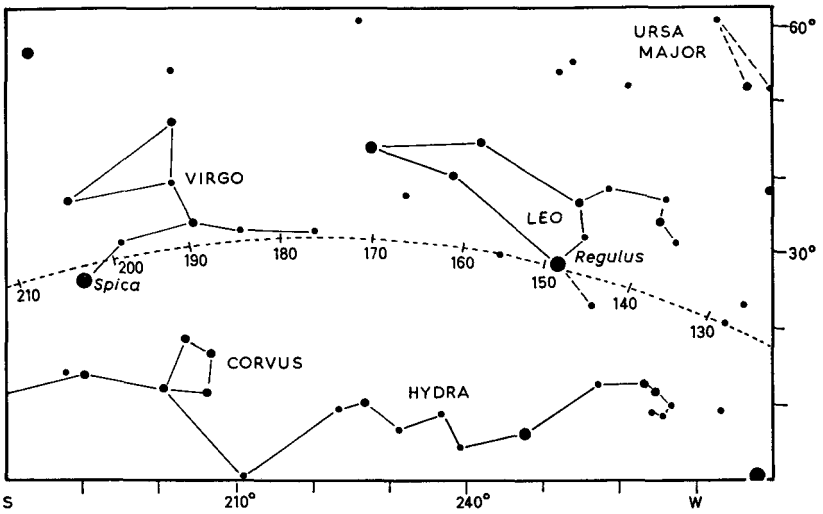


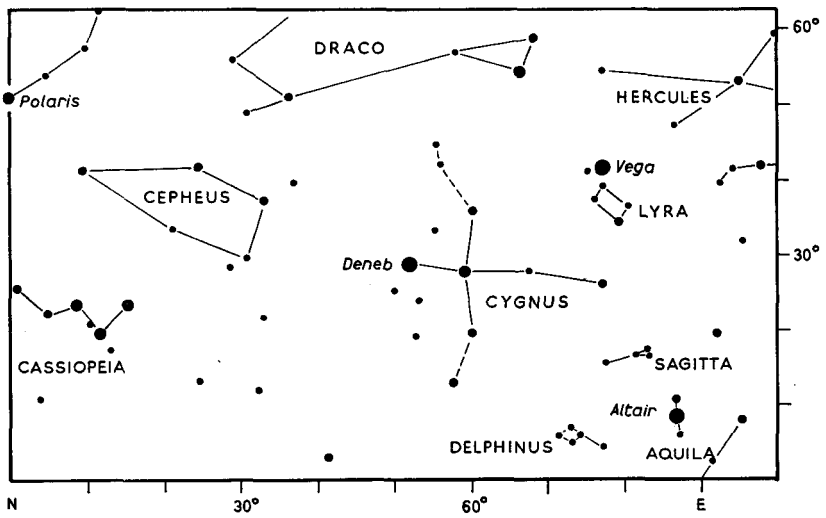
5L

January 6 at 7h	January 21 at 6h
February 6 at 5h	February 21 at 4h
March 6 at 3h	March 21 at 2h
April 6 at 1h	April 21 at midnight
May 6 at 23h	May 21 at 22h



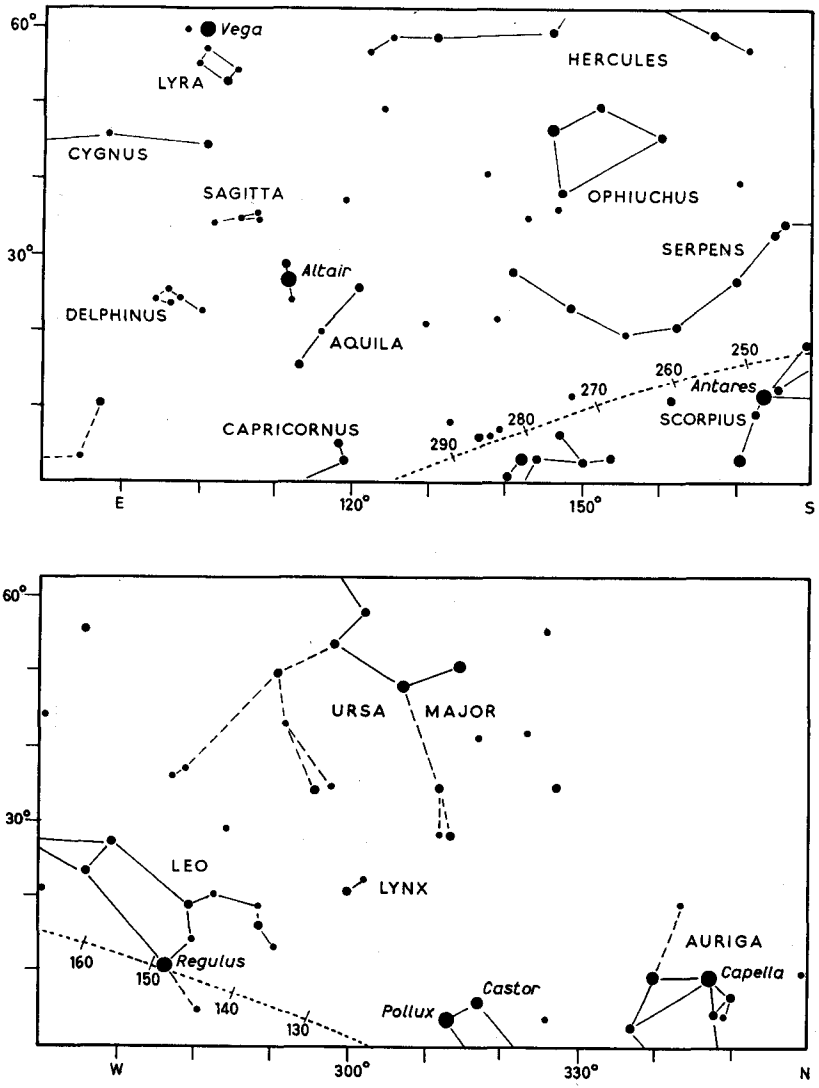
January 6 at 7h	January 21 at 6h	**5R**
February 6 at 5h	February 21 at 4h	
March 6 at 3h	March 21 at 2h	
April 6 at 1h	April 21 at midnight	
May 6 at 23h	May 21 at 22h	





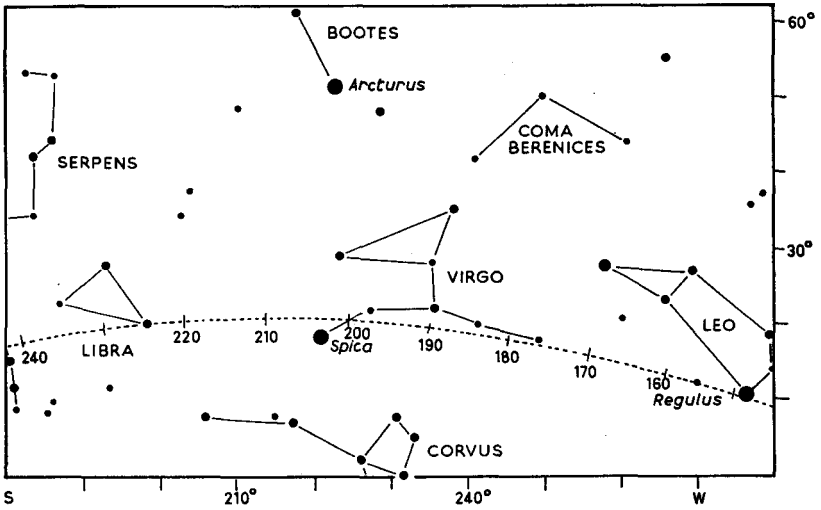
6L

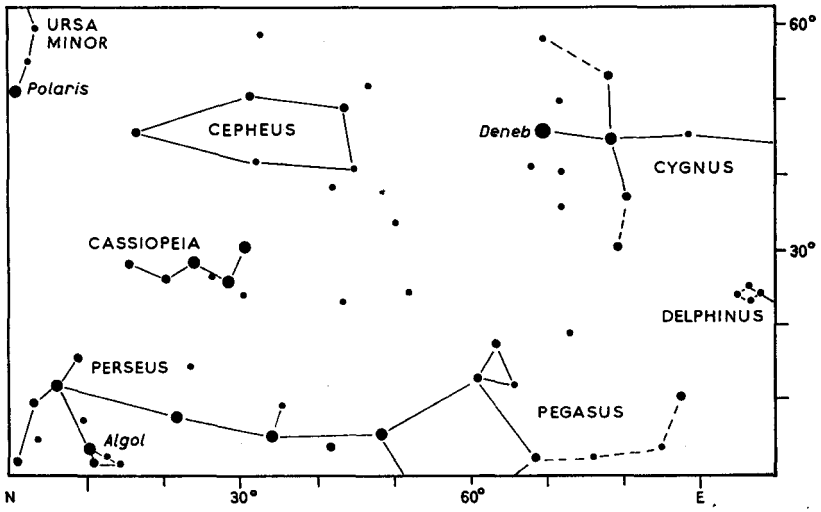
March 6 at 5h	March 21 at 4h
April 6 at 3h	April 21 at 2h
May 6 at 1h	May 21 at midnight
June 6 at 23h	June 21 at 22h
July 6 at 21h	July 21 at 20h



March 6 at	5^h	March 21 at	4^h
April 6 at	3^h	April 21 at	2^h
May 6 at	1^h	May 21 at	midnight
June 6 at	23^h	June 21 at	22^h
July 6 at	21^h	July 21 at	20^h

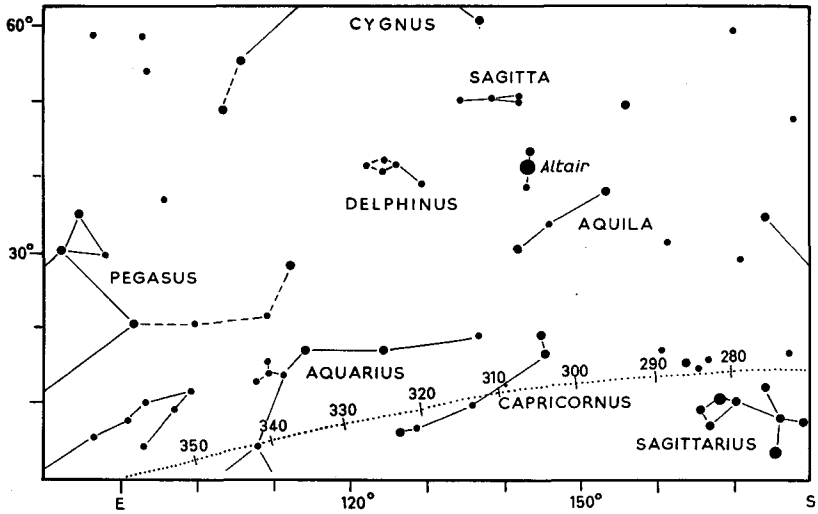
6R

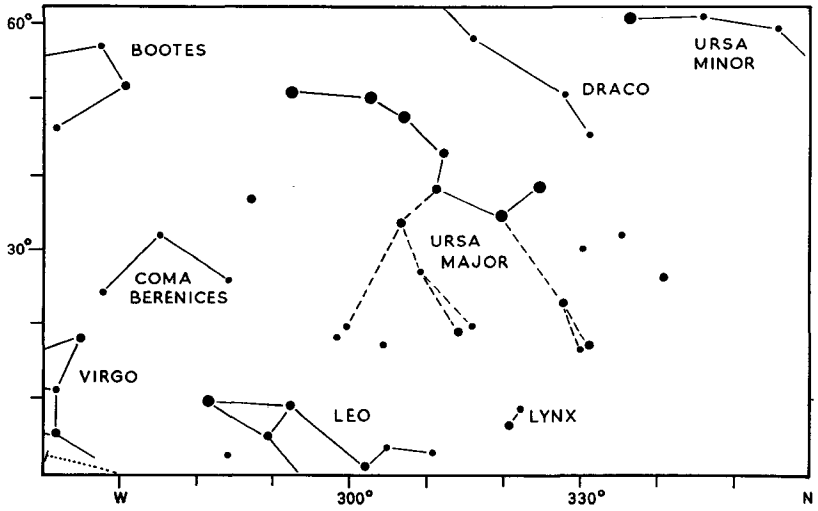




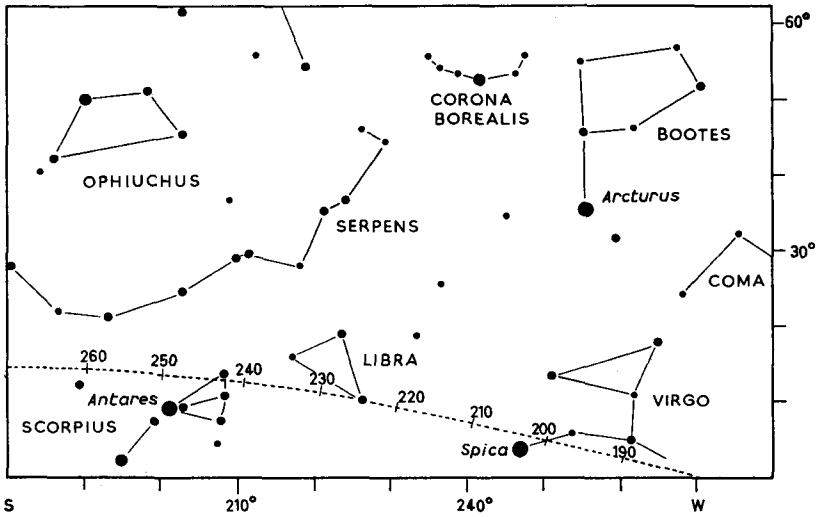
7L

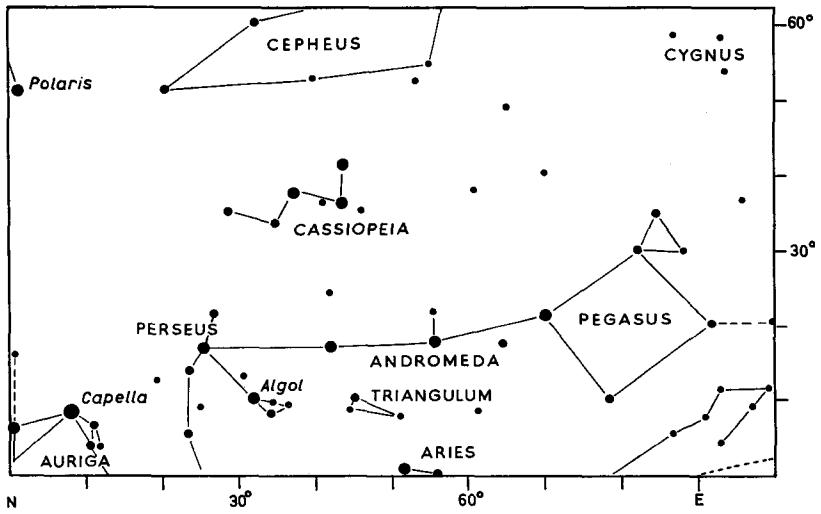
May 6 at 3h	May 21 at 2h
June 6 at 1h	June 21 at midnight
July 6 at 23h	July 21 at 22h
August 6 at 21h	August 21 at 20h
September 6 at 19h	September 21 at 18h





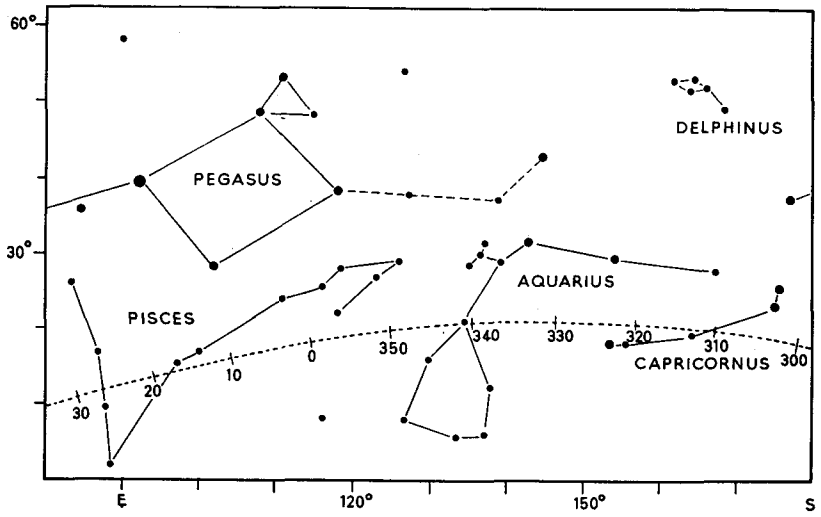
May 6 at 3h	May 21 at 2h	**7R**
June 6 at 1h	June 21 at midnight	
July 6 at 23h	July 21 at 22h	
August 6 at 21h	August 21 at 20h	
September 6 at 19h	September 21 at 18h	

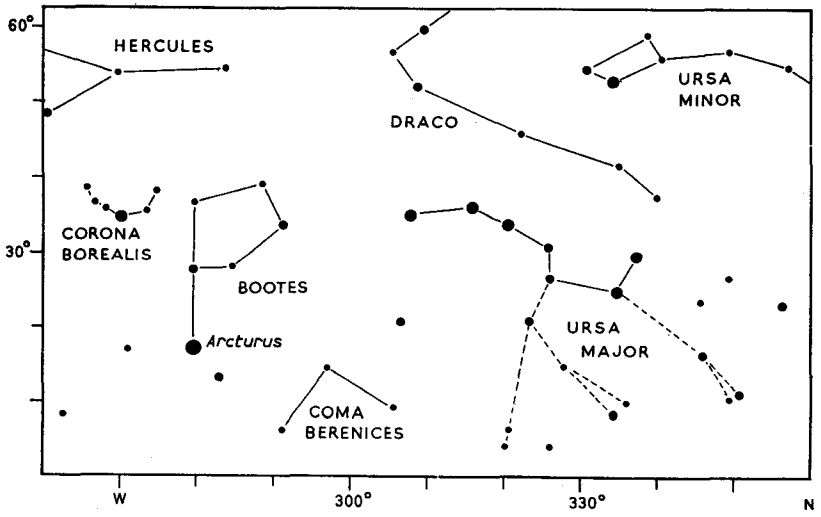




8L

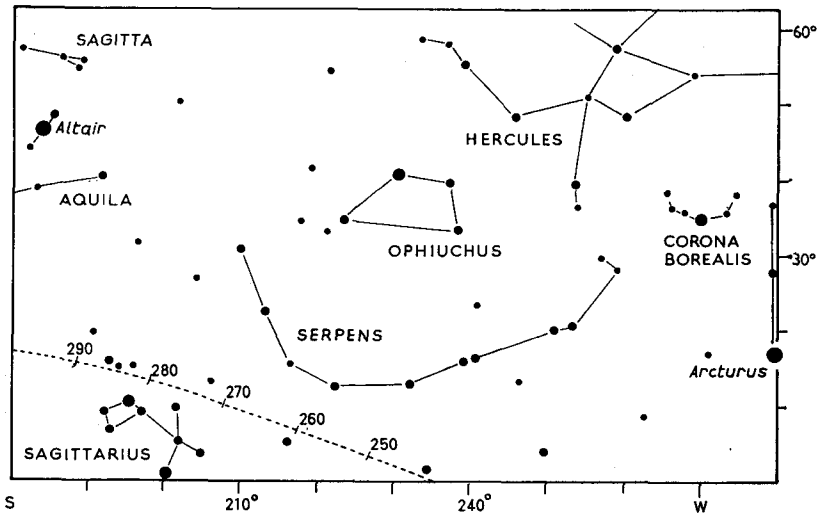
July 6 at 1h	July 21 at midnight
August 6 at 23h	August 21 at 22h
September 6 at 21h	September 21 at 20h
October 6 at 19h	October 21 at 18h
November 6 at 17h	November 21 at 16h

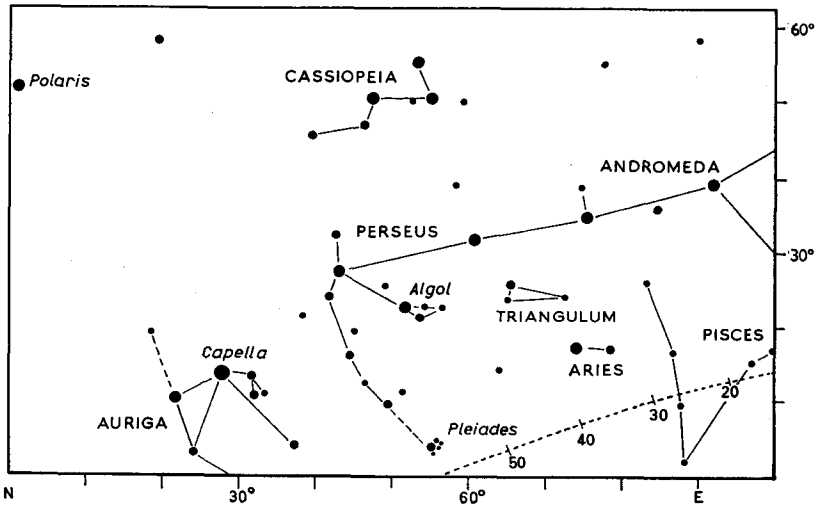




July 6 at 1h	July 21 at midnight
August 6 at 23h	August 21 at 22h
September 6 at 21h	September 21 at 20h
October 6 at 19h	October 21 at 18h
November 6 at 17h	November 21 at 16h

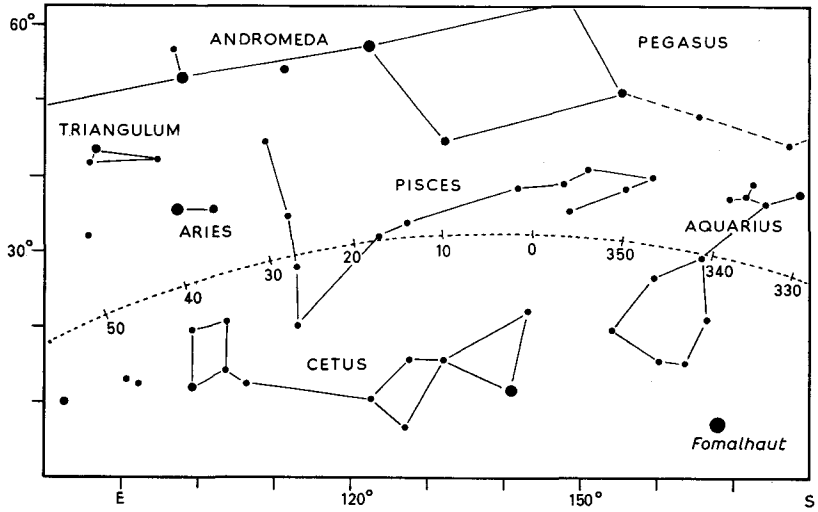
8R

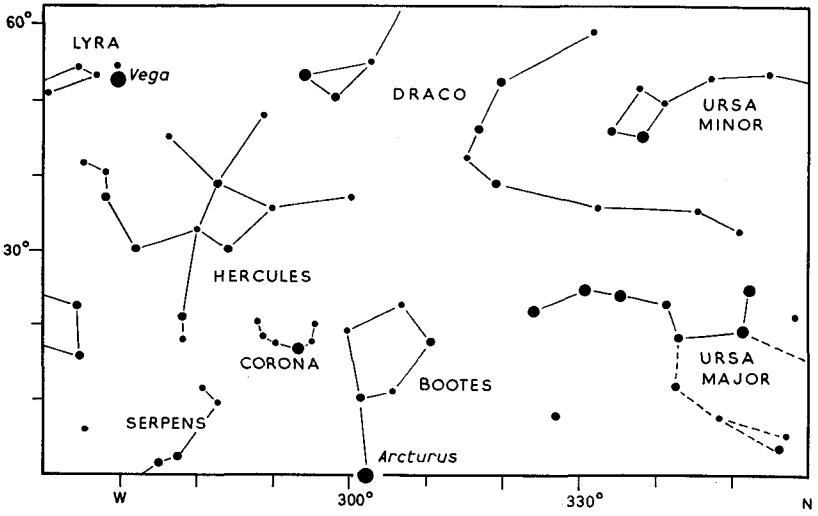




9L

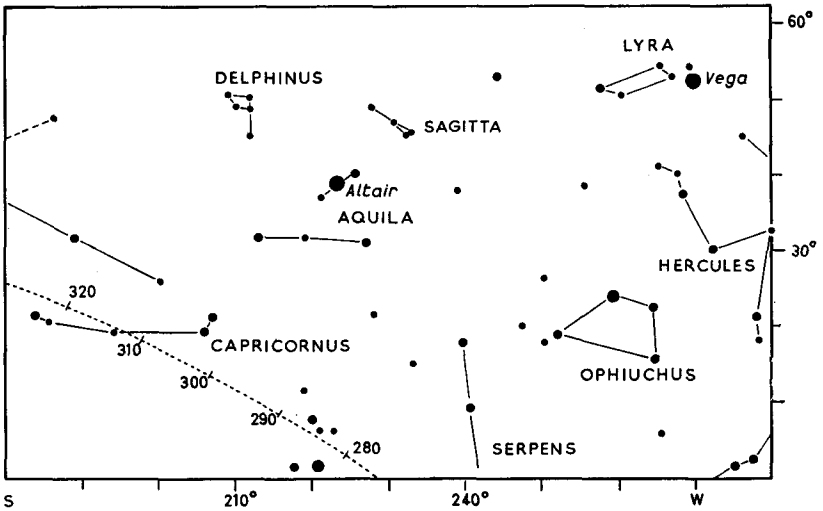
August 6 at 1h	August 21 at midnight
September 6 at 23h	September 21 at 22h
October 6 at 21h	October 21 at 20h
November 6 at 19h	November 21 at 18h
December 6 at 17h	December 21 at 16h

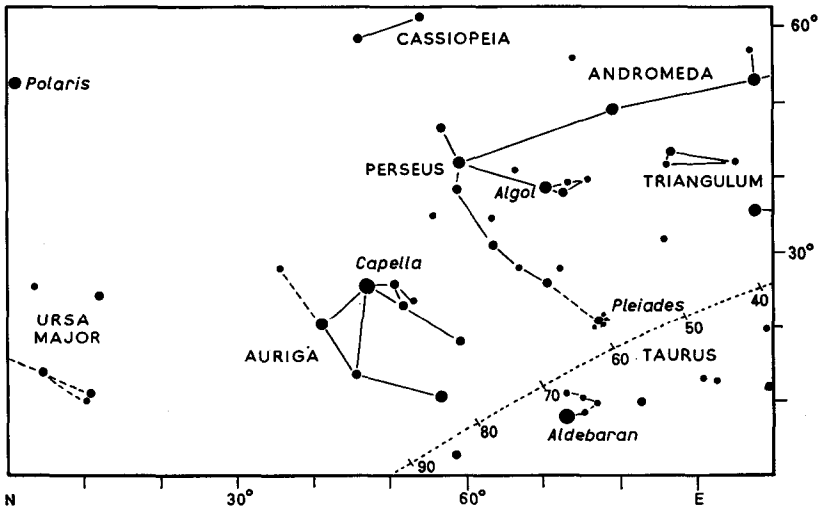




August 6 at 1h	August 21 at midnight
September 6 at 23h	September 21 at 22h
October 6 at 21h	October 21 at 20h
November 6 at 19h	November 21 at 18h
December 6 at 17h	December 21 at 16h

9R





10L

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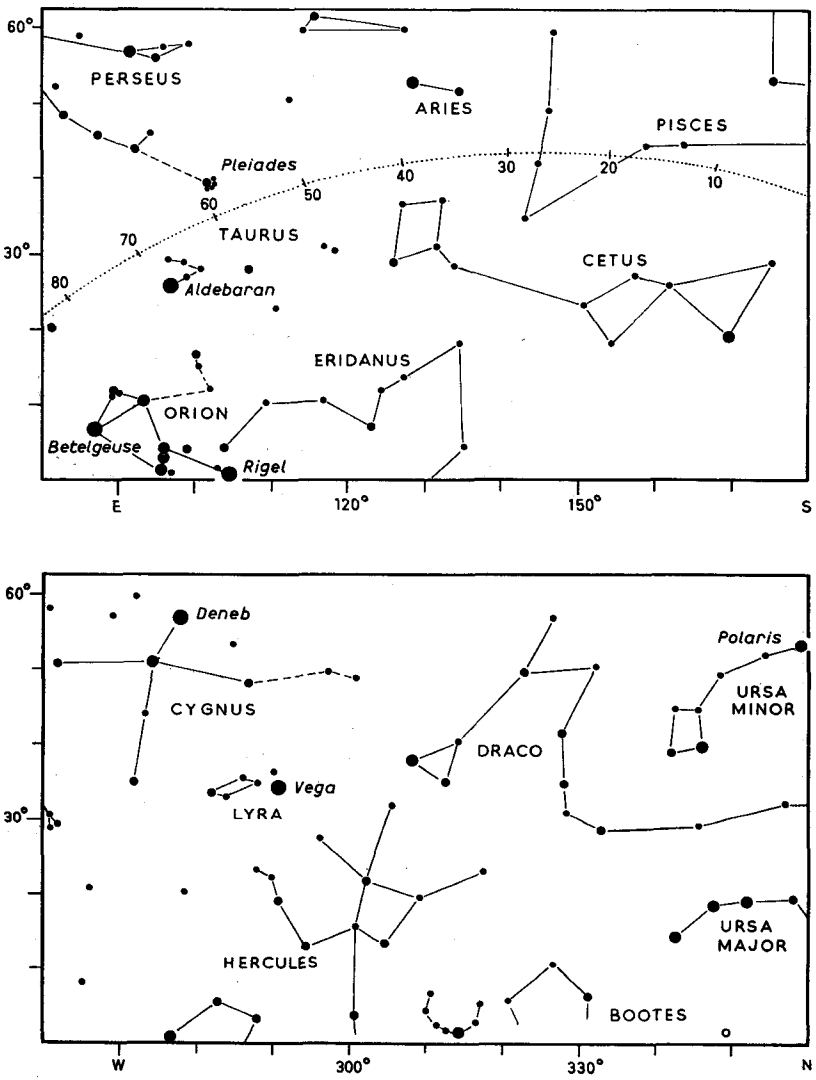
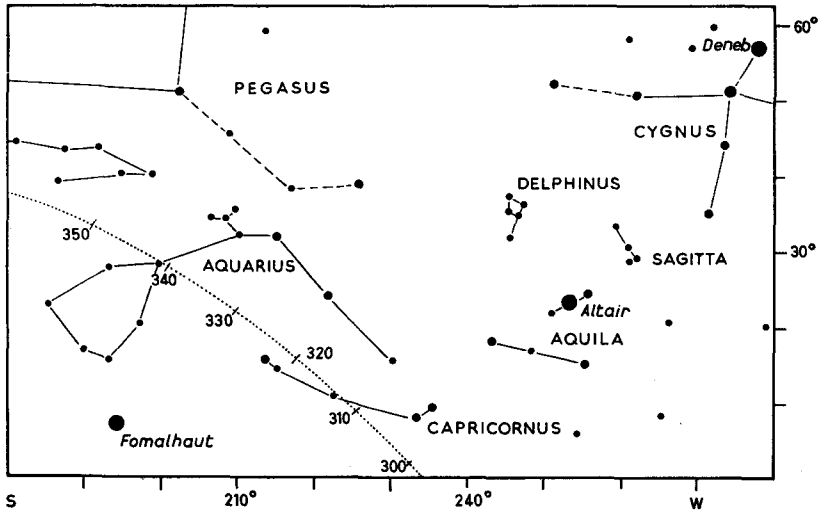
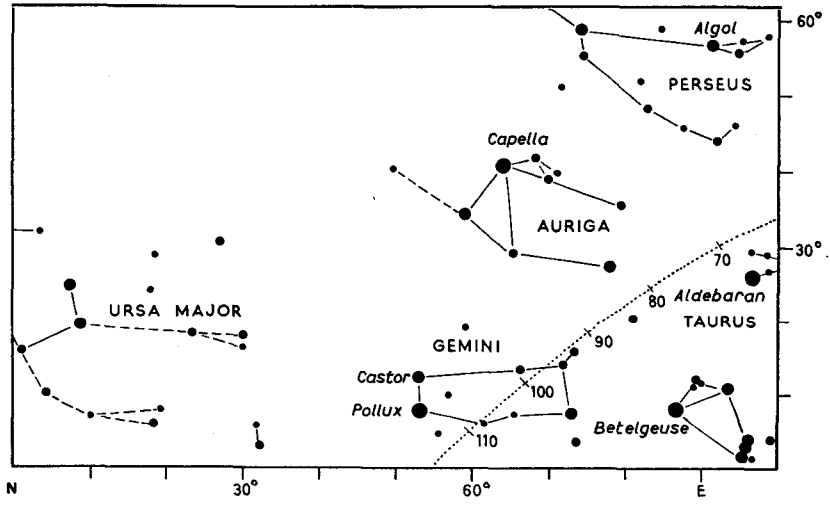
October 6 at 23h	October 21 at 22h
November 6 at 21h	November 21 at 20h
December 6 at 19h	December 21 at 18h



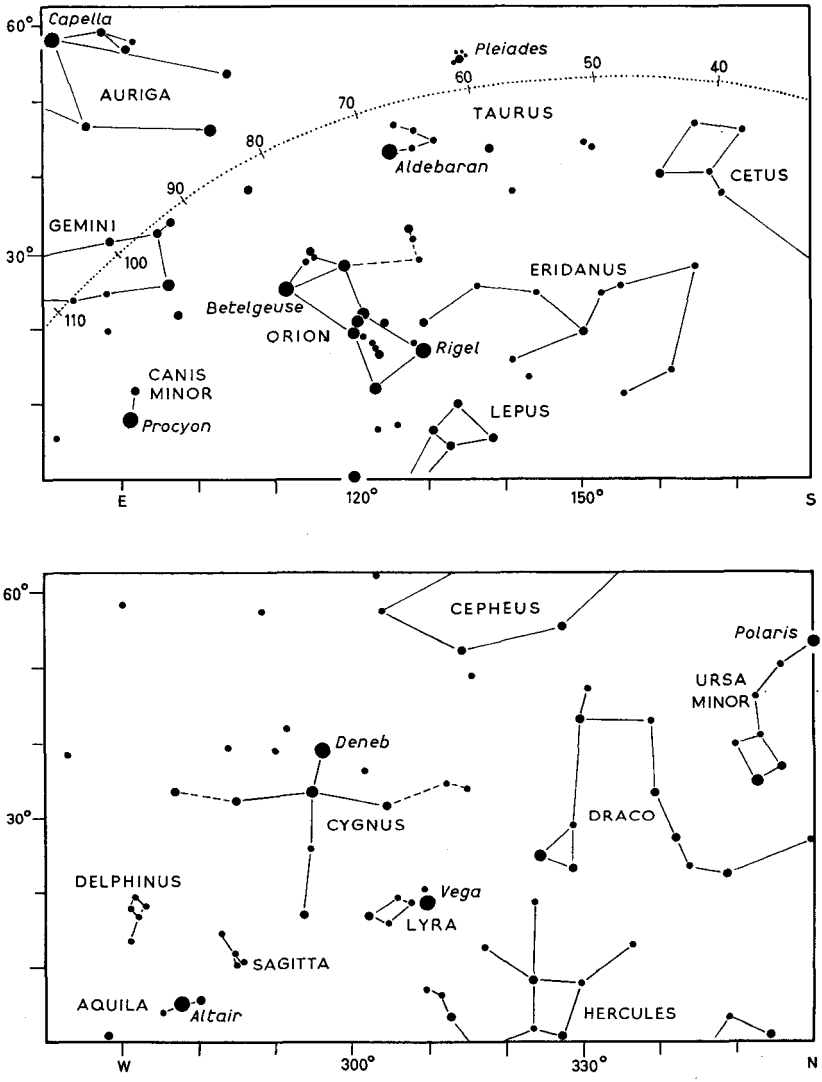
August 6 at 3h	August 21 at 2h	**10R**
September 6 at 1h	September 21 at midnight	
October 6 at 23h	October 21 at 22h	
November 6 at 21h	November 21 at 20h	
December 6 at 19h	December 21 at 18h	



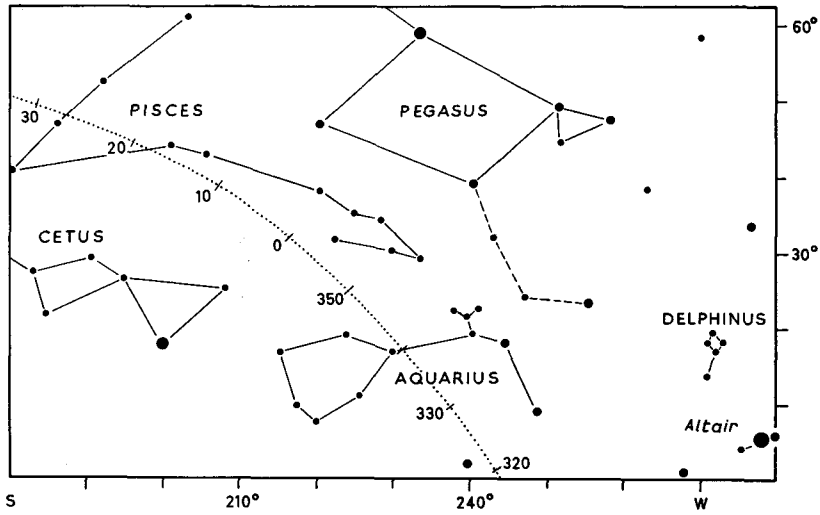


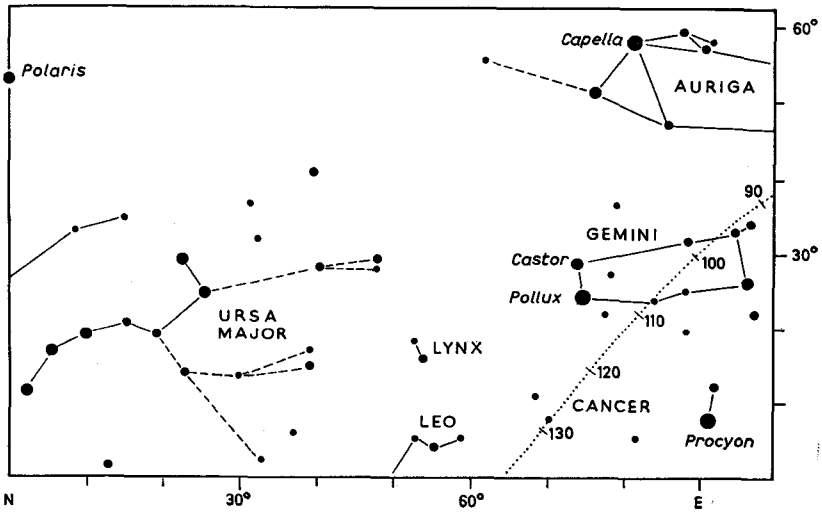
11L

September 6 at 3h	September 21 at 2h
October 6 at 1h	October 21 at midnight
November 6 at 23h	November 21 at 22h
December 6 at 21h	December 21 at 20h
January 6 at 19h	January 21 at 18h



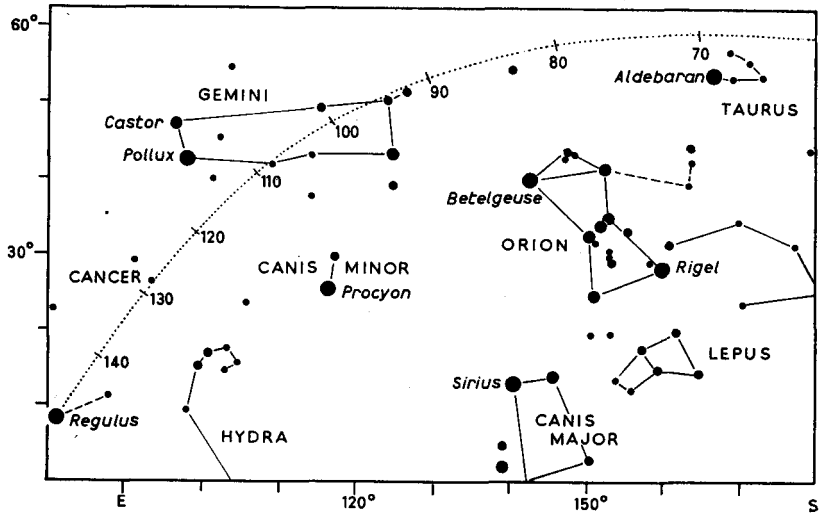
September 6 at 3h	September 21 at 2h	**11R**
October 6 at 1h	October 21 at midnight	
November 6 at 23h	November 21 at 22h	
December 6 at 21h	December 21 at 20h	
January 6 at 19h	January 21 at 18h	

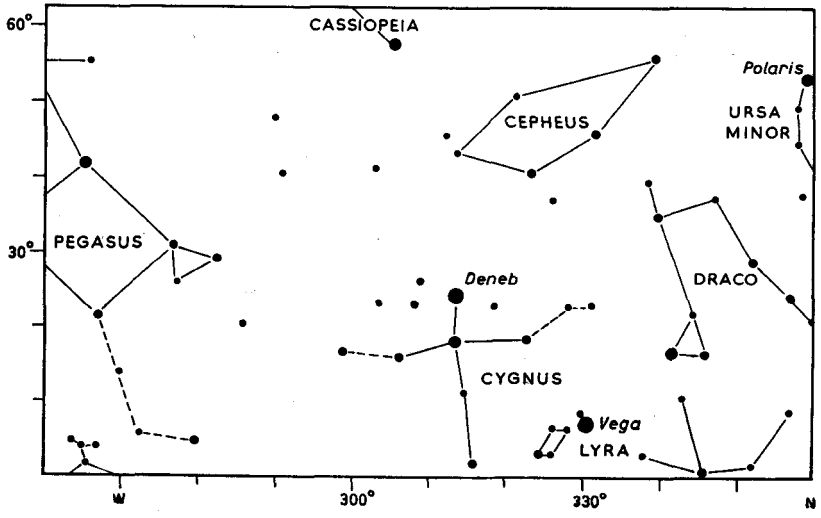




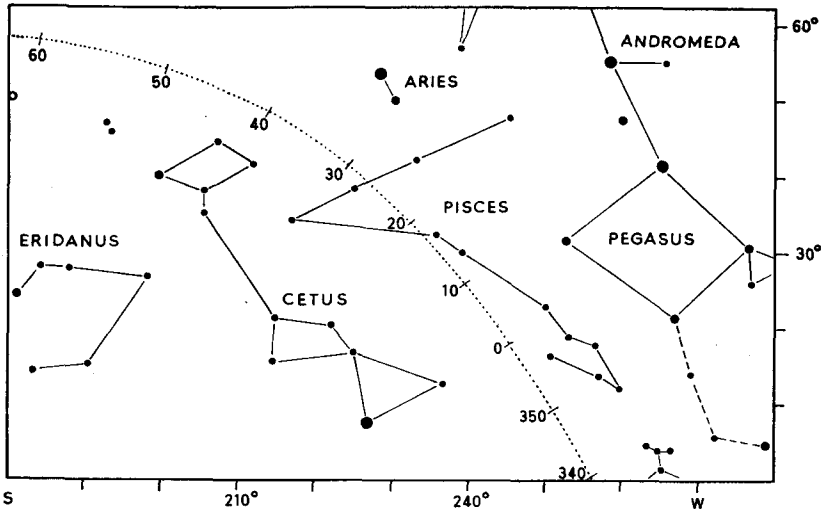
12L

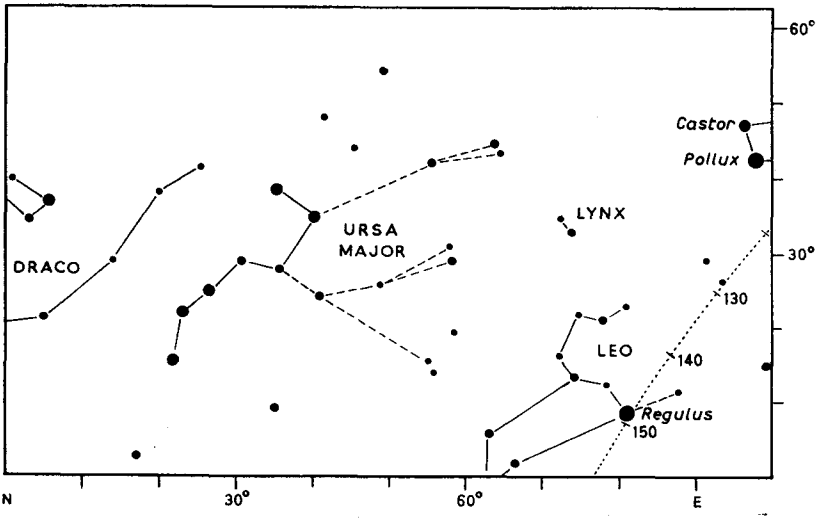
October 6 at 3h	October 21 at 2h
November 6 at 1h	November 21 at midnight
December 6 at 23h	December 21 at 22h
January 6 at 21h	January 21 at 20h
February 6 at 19h	February 21 at 18h

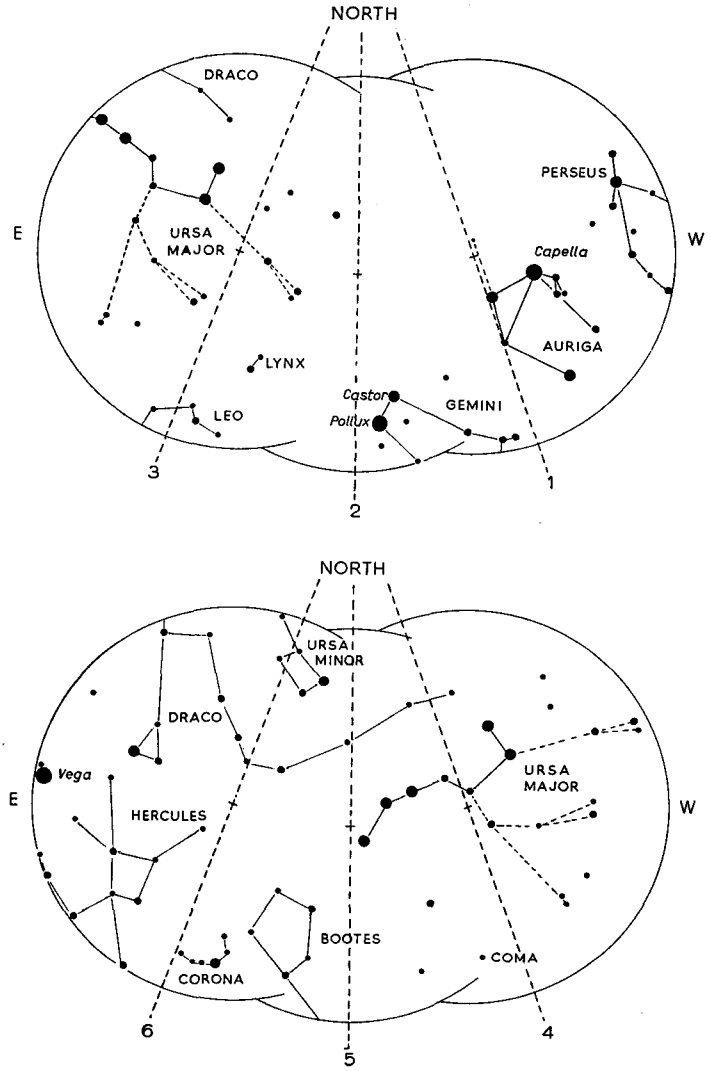




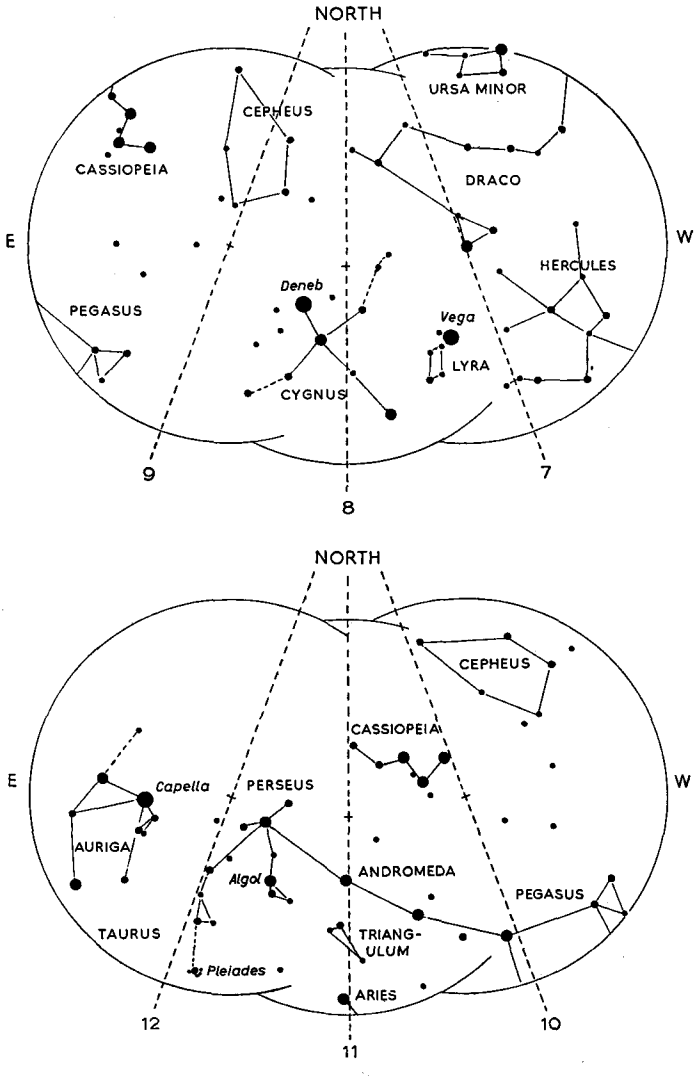
October 6 at 3h	October 21 at 2h	**12R**
November 6 at 1h	November 21 at midnight	
December 6 at 23h	December 21 at 22h	
January 6 at 21h	January 21 at 20h	
February 6 at 19h	February 21 at 18h	







Overhead stars



Overhead stars

The Planets in 1963

DATE		*Venus*	*Mars*	*Jupiter*	*Saturn*	*Uranus*	*Neptune*
January	6	240°	145°	340°	311°	155°	226°
	21	254°	142°	343°	312°	155°	226°
February	6	270°	136°	347°	314°	154°	226°
	21	287°	130°	350°	316°	154°	226°
March	6	302°	127°	353°	318°	153°	226°
	21	319°	126°	357°	319°	152°	226°
April	6	339°	128°	1°	321°	152°	226°
	21	357°	132°	4°	322°	152°	225°
May	6	15°	138°	8°	323°	151°	225°
	21	33	144°	11°	323°	151°	224°
June	6	52°	152°	14°	323°	152°	224°
	21	70°	160°	16°	323°	152°	224°
July	6	88°	168°	18°	323°	153°	224°
	21	107°	177°	19°	322°	154°	223°
August	6	126°	186°	20°	321°	154°	223°
	21	145°	195°	20°	320°	155°	224°
September	6	165°	206°	19°	319°	156°	224°
	21	184°	216°	17°	318°	157°	224°
October	6	202°	226°	15°	317°	158°	225°
	21	221°	236°	13°	317°	159°	225°
November	6	241°	248°	12°	317°	160°	226°
	21	259°	259°	10°	318°	160°	226°
December	6	278°	270°	10°	319°	160°	227°
	21	297°	282°	11°	320°	160°	227°
Conjunction:							
Superior		Aug. 30	—	Mar. 16	Feb. 3	Aug. 29	Nov. 8
Opposition:		—	Feb. 4	Oct. 8	Aug. 13	Feb. 22	May 5

Mercury moves so quickly among the stars that it is not possible to indicate its position on the star charts at a convenient interval. The monthly notes must be consulted for the best times at which this planet may be seen.

The positions of the other planets are given in the table on the opposite page. This gives the apparent longitudes on dates which correspond to those of the star charts, and the position of the planet may at once be found near the ecliptic at the given longitude.

Examples:

(1) *What is the bright planet seen to the right of Regulus at 1 a.m. (Summer Time) on January 15?*
The time is 0^h G.M.T. and from the table on page 2 the appropriate star chart is found to be number 2. The longitude of the planet is then seen to be about 140 degrees, and from the table opposite it is identified as Mars.

(2) *Where can Saturn be found on November 15?*
From the table opposite, Saturn is found to have passed opposition, so that it is an evening star; the longitude is found to be about 317 degrees. Using charts 8, 9 or 10, as indicated on page 2 for November evenings, Saturn is found to be in the south-west after sunset, in the constellation Capricornus.

Phases of the Moon, 1963

New Moon			*First Quarter*			*Full Moon*			*Last Quarter*		
Jan.	25d	13h 42m	Jan.	3d	01h 02m	Jan.	9d	23h 08m	Jan.	17d	20h 34m
Feb.	24	02 06	Feb.	1	08 50	Feb.	8	14 52	Feb.	16	17 38
Mar.	25	12 10	Mar.	2	17 17	Mar.	10	07 49	Mar.	18	12 08
Apr.	23	20 29	Apr.	1	03 15	Apr.	9	00 57	Apr.	17	02 52
May	23	04 00	May	30	15 08	May	8	17 23	May	16	13 36
June	21	11 46	June	28	20 24	June	7	08 31	June	14	20 53
July	20	20 43	July	28	13 13	July	6	21 55	July	14	01 57
Aug.	19	07 35	Aug.	27	06 54	Aug.	5	09 31	Aug.	12	06 21
Sept.	17	20 51	Sept.	26	00 38	Sept.	3	19 34	Sept.	10	11 42
Oct.	17	12 43	Oct.	25	17 20	Oct.	3	04 44	Oct.	9	19 27
Nov.	16	06 50	Nov.	24	07 56	Nov.	1	13 55	Nov.	8	06 37
Dec.	16	02 06	Dec.	23	19 54	Dec.	30	23 54	Dec.	7	21 34
						Dec.	30	11 04			

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The Planets and the Ecliptic

The paths of the planets about the Sun all lie close to the plane of the ecliptic, which is marked for us in the sky by the apparent path of the Sun among the stars, and is shown on the star charts by a broken line. The Moon and planets will always be found close to this line, never departing from it by more than about 7 degrees. Thus the planets are most favourably placed for observation when the ecliptic is well displayed, and this means that it should be as high in the sky as possible. This avoids the difficulty of finding a clear horizon, and also overcomes the problem of atmospheric absorption, which greatly reduces the light of the stars. Thus a star at an altitude of 10 degrees suffers a loss of 60 per cent of its light, which corresponds to a whole magnitude; at an altitude of only 4 degrees, the loss may amount to two magnitudes.

The position of the ecliptic in the sky is therefore of great importance, and since it is tilted at about $23\frac{1}{2}$ degrees to the equator, it is only at certain times of the day or year that it is displayed to the best advantage. It will be realized that the Sun (and therefore the ecliptic) is at its highest in the sky at noon in midsummer, and at its lowest at noon in midwinter. Allowing for the daily motion of the sky, these times lead to the fact that the ecliptic is highest at midnight in winter, at sunset in the spring, at noon in summer, and at sunrise in the autumn. Hence these are the best times to see the planets. Thus, if Venus is an evening star, in the western sky after sunset, it will be seen to best advantage if this occurs in the spring, when the ecliptic is high in the sky and slopes down steeply to the north-west. This means that the planet is not only higher in the sky, but will remain for a much longer period above the horizon. For similar reasons, a morning star will be seen at its best on autumn mornings before sunrise, when the ecliptic is high in the east. The outer planets, which can come to opposition and are then in the south at midnight, are best seen when opposition occurs in the winter months. Clearly the summer is the least favourable time to observe the planets, for the ecliptic is always low in the sky on summer nights.

Notes on the Planets in the monthly diagrams

The following general notes on observing the planets are followed by detailed month-by-month accounts of the behaviour of the planets, and of other interesting phenomena. These monthly notes include diagrams of the planetary orbits, and of the apparent movements of the planets at favourable times of the year. Additional notes on other astronomical phenomena will be found on the following pages.

The monthly diagrams of the orbits of the planets are intended to give a picture of the way in which the planets move about the Sun during the month. These diagrams are similar to those that were given many years ago in the old *English Mechanic*, and which were also adopted for some time in the *Journal* of the B.A.A. The motions of the planets are all anti-clockwise, and the movement during the month is indicated by the thickened line; the longitudes are measured from the Equinox, marked 0°. It is difficult to show all the orbits to scale, since the distance of Pluto from the Sun is about a hundred times that of Mercury. For this reason, only the orbits of the inner planets (Mercury to Mars) are shown to scale, those of the outer planets being merely suggested in the diagrams. A line drawn from the Earth to any other planet will give a rough idea of the apparent longitude of that body, but a more accurate value can be obtained from the table on page 30, and this will enable the position of the planet to be found on the monthly star-charts.

The inferior planets, Mercury and Venus, move in smaller orbits than that of the Earth, and so are always seen near the Sun. They are most obvious at the times of greatest angular distance from the Sun (greatest elongation), which may reach 28 degrees for Mercury, or 47 degrees for Venus. They are then seen as evening stars in the western sky after sunset (at eastern elongations) or as morning stars in the eastern sky before sunrise (at western elongations). The succession of phenomena, conjunctions and elongations, always follows the same order, but the intervals

between them are not equal. Thus if either planet is moving round the far side of its orbit its motion will be to the east, in the same direction in which the Sun appears to be moving. It therefore takes much longer for the planet to overtake the Sun – that is, to come to superior conjunction – than it does when moving round to inferior conjunction, between Sun and Earth. The intervals given in the following table are average values; they remain fairly constant in the case of Venus, which travels in an almost circular orbit. In the case of Mercury, however, conditions vary widely because of the great eccentricity and inclination of the planet's orbit.

			Mercury	*Venus*
Inferior conj.	to	Elongation West	22 days	72 days
Elongation West	to	Superior conj.	36 days	220 days
Superior conj.	to	Elongation East	36 days	220 days
Elongation East	to	Inferior conj.	22 days	72 days

The greatest brilliancy of Venus always occurs about a month *before* greatest western elongation (as a morning star), or a month *after* greatest eastern elongation (as an evening star). No such rule can be given for Mercury, because its distance from Sun and Earth can vary over a wide range.

Mercury is not likely to be seen unless a clear horizon is available; it is seldom seen as much as 10 degrees above the horizon in the twilight sky. In general it may be said that the most favourable times for seeing Mercury as an evening star will be in spring, some days before greatest eastern elongation; in autumn it may be seen as a morning star some days after greatest western elongation.

Venus is the brightest of the planets, and may be seen on occasions in broad daylight. Like Mercury, it is alternately a morning and an evening star, and will be highest in the sky when it is a morning star in autumn, or an evening star in spring. Venus is seen to best advantage when it comes to greatest eastern elongation in June; it is then well north of the Sun in the spring months and is a brilliant object in the sunset sky over a long period.

The superior planets, which travel in orbits larger than that of the Earth, differ from Mercury and Venus in that they can be seen opposite the Sun in the sky. The superior planets are morning stars after conjunction with the Sun, rising earlier each day until they

come to opposition. They will then be in the south at midnight, and visible all night. After opposition, they are evening stars, setting earlier each evening until they set in the west with the Sun at the next conjunction. The interval between conjunctions or between oppositions is greatest for Mars (over two years). At the time of opposition, the planet is nearest the Earth, and therefore at its brightest. This change in brightness is most noticeable with Mars, whose distance from the Earth can vary considerably; the other superior planets are at such great distances that there is very little change in brightness from one opposition to another. The effect of altitude is, however, of importance, for at a December opposition the planet will be among the stars of Taurus or Gemini, and can then be at an altitude of more than 60 degrees in southern England. At a summer opposition, when the planet is in Sagittarius, it may only rise to about 15 degrees above the southern horizon, and so make a less impressive appearance.

Mars, whose orbit is appreciably eccentric, comes nearest to the Earth at an opposition at the end of August; it may then be brighter even than Jupiter, but rather low in the sky in Aquarius. These favourable oppositions occur every fifteen or seventeen years (1924, 1941, 1956, 1973), but in this country the planet is probably better seen at an opposition in the autumn or winter, when it is higher in the sky. Oppositions of Mars occur at an average interval of 780 days, and during this time the planet makes a complete circuit of the sky.

Jupiter is always a bright planet, and comes to opposition a month later each year, having moved, roughly speaking, from one zodiacal constellation to the next.

Saturn moves much more slowly than Jupiter, and may remain in the same constellation for several years. The brightness of Saturn depends on the aspect of its rings, as well as on the distance from Earth and Sun. At present the rings are well open, so that the planet is quite a bright object.

Uranus, *Neptune* and *Pluto* are hardly likely to attract the attention of observers without adequate instruments, but some notes on their present positions in the sky will be found in the February and May notes.

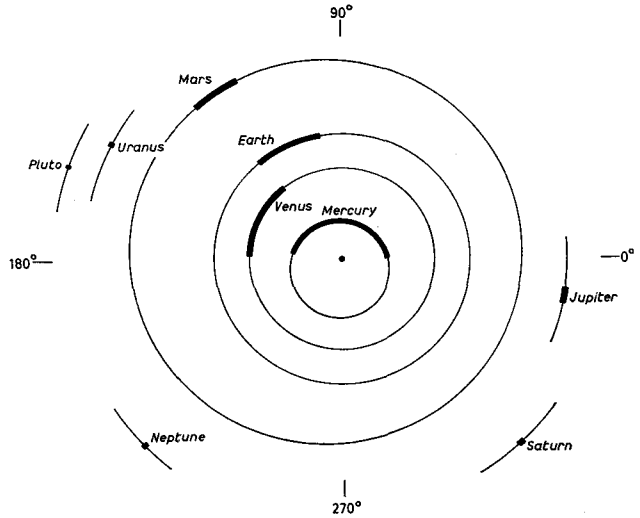
Monthly Notes, 1963

January

Full Moon: January 9 *New Moon:* January 25

EARTH is at perihelion (nearest to the Sun) on January 4, when its distance from the Sun will be 91,400,000 miles.

MERCURY is at greatest eastern elongation (19 degrees; evening star) on January 4, and there is just a chance that the planet may be seen in the first few days of the month, low in the south-west after sunset. Mercury is at inferior conjunction on January 20, and after this date it becomes a morning star.

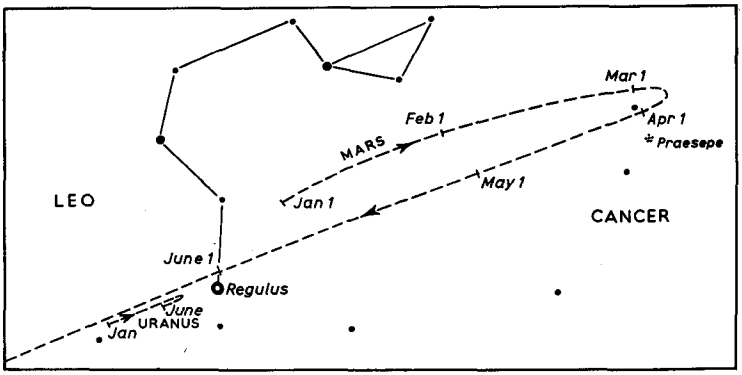


Planetary Orbits in January

VENUS will not be a very conspicuous object in 1963, and there will be no real opportunity to see this brilliant planet against a dark sky. The most favourable appearance of Venus will be at the beginning of January, when it is a morning star, rising in the south-east about four hours before the Sun; greatest western elongation occurs on January 23 (47 degrees), the magnitude of the

planet being then −4·3. The planet is west of the Sun and is moving south (while the Sun moves north), and the period of visibility before sunrise rapidly diminishes.

MARS is a brilliant evening star, rising in the east in the early evening; it will be seen near the Sickle of Leo (see diagram below), and is moving west (retrograde) as it approaches opposition. Mars gains rapidly in brightness during the month and may readily be distinguished by its colour and the fact that it is much brighter than any stars in its neighbourhood.



Mars and Uranus. January–June, 1963

JUPITER is also a brilliant evening star, but is in the west, setting in mid-evening. It is moving direct in Aquarius, and will be seen under the right-hand side of the Great Square of Pegasus at the end of January. Jupiter passes about ¾ degree south of the fourth magnitude star Lambda Aquarii on January 10; this is the third conjunction of the planet with the star at this opposition, the previous two taking place on May 28 and August 7, 1962, as referred to in the last year's *Yearbook*.

SATURN is also an evening star, but is now approaching conjunction and sets in the south-west shortly after the Sun. It may be seen in the first half of the month as a bright star (magnitude +0·9) among the stars of Capricornus.

A penumbral eclipse of the Moon occurs on the night of January 9, lasting from $21^h\ 04^m$ until $1^h\ 34^m$ on the 10th. The slight change in the light of the Moon caused by the passage of the outer parts of the Earth's shadow is not visible to the naked eye.

An annular eclipse of the Sun takes place on January 25, but this will be visible only from the southern parts of South America and Africa, and in Antarctica.

Phases of the Inner Planets. Although it is often stated in textbooks that the inferior planets, Mercury and Venus, show phases like the Moon, it is seldom made clear that these take place in the reverse order. We are accustomed to seeing our Moon as a thin crescent in the western sky at sunset, with the horns pointing to the left (east), and this phase is followed by First Quarter, Full Moon and Last Quarter – a succession of phases which are summed up in the words *waxing* and *waning*. The inferior planets certainly do the same thing, but the Moon moves *eastwards* round the Earth, while the planets move *westwards* from inferior conjunction. They appear soon after conjunction as morning stars, first showing a thin crescent with the horns pointing to the *right* (west). The crescent grows larger until the planet is at western elongation, when it appears half illuminated, like the Moon at Last Quarter. Then follows the gibbous phase, and this increases until the planet, on the far side of its orbit, reaches superior conjunction, when it appears like the Full Moon. It then appears as an evening star, and the illuminated portion diminishes; at eastern elongation it appears half illuminated again, but is now like the First Quarter of the Moon. After this date the planet shows the crescent phase, but the horns of the crescent now point to the *east*.

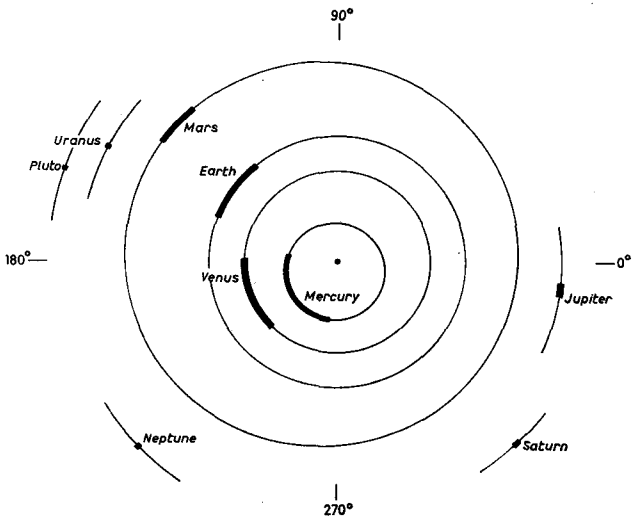
In 1963 Venus may be seen in the crescent phase in a small telescope for the first three weeks of January; it appears like the Moon at Last Quarter on January 23, and for the rest of the year it is in the gibbous phase, more than half illuminated.

February

Full Moon: February 8 *New Moon:* February 24

MERCURY is at greatest western elongation on February 13 (26 degrees; morning star), but it is then well south of the Sun and is unlikely to reach even 5 degrees altitude in the sky at dawn.

VENUS is a morning star, rising in the south-east about two hours before the Sun, and is not quite as bright as it was at the beginning of the year. Its elongation from the Sun changes only very slowly, but the planet reaches its most southerly declination during the month, so that it is seen at a lower altitude and for a shorter time before sunrise.



Planetary Orbits in February

MARS is at opposition on February 4, and is then visible all night; it is moving westwards in Cancer towards the star cluster *Praesepe* (see diagram on page 37). Mars is actually nearest to the Earth on February 3, but as the planet is approaching aphelion, the distance is then 62 million miles, so that this is not a very favourable

opposition. It is interesting to notice how quickly the planet increases in brightness before opposition, and decreases after it. By the end of February it has again sunk to magnitude −0·5. The opposition magnitude of −1·0 indicates that the planet at this opposition is only about a quarter as bright as it can be at an August opposition, when the distance from the Earth is as little as 35 million miles, and the magnitude may reach −2·5. The north pole of Mars is tilted towards the Earth and Sun, so that it is summer in the northern hemisphere of Mars.

JUPITER is an evening star, visible in the west for a short time after sunset in the constellation Aquarius. It moves into Pisces at the end of the month, when it sets only an hour after the Sun. The magnitude is now only −1·6.

SATURN is no longer visible, since the planet is now on the far side of its orbit, and is in conjunction with the Sun on February 3.

URANUS comes to opposition on February 22, and is to be found in the same part of the sky as Mars. As will be seen from the diagram on page 37, the planet is to be found near the bright star *Regulus* in Leo. Its magnitude is +5·7, so that it should be just possible to see the planet with the naked eye; in a small telescope it appears as a greenish disc. The distance of Uranus at opposition is about 1,610 million miles from the Earth.

The eight-year cycle of Venus. The orbit of Venus is so nearly circular, and perturbations of this planet are always so small, that the successive phenomena of conjunctions and elongations occur at very regular intervals (see page 34). The complete synodic period amounts to 583·92 days, and it so happens that five of these periods (=2,919·6 days) are almost exactly equal to eight years (=2,921·9 days), there being a discrepancy of only two days. Thus all the phenomena of Venus repeat themselves after eight years under almost identical conditions, the elongations and conjunctions occurring at about the same date and in the same part of the sky. The following table shows the dates on which these phenomena occur during the eight years 1956 to 1964, and the striking regularity of the events may at once be seen; in the cycle that

follows, all the phenomena will occur two days earlier (with a possible error of one day):

	Eastern elongation	*Inferior conjunction*	*Western elongation*	*Superior conjunction*
1956	Apr. 12	June 22	Aug. 31	—
1957	Nov. 18	—	—	Apr. 14
1958	—	Jan. 28	Apr. 8	Nov. 11
1959	June 23	Sept. 1	Nov. 11	—
1960	—	—	—	June 22
1961	Jan. 29	Apr. 10	June 20	—
1962	Sept. 3	Nov. 12	—	Jan. 27
1963	—	—	Jan. 23	Aug. 30
1964	Apr. 10	June 19	Aug. 29	—

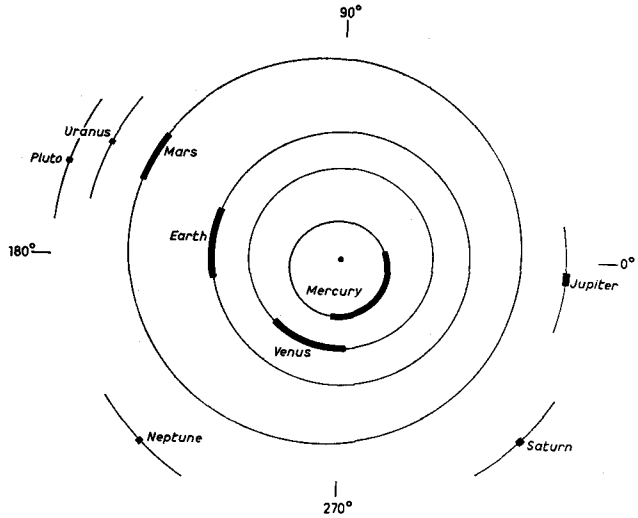
One curious result of the regularity of the Venus cycle is that the phenomena of the planet can only occur in the months of January, April, June, August (or early September) and November. The best display of Venus as an evening star is given when the planet is at greatest eastern elongation in June. It is then east of the Sun, and since the ecliptic slopes steeply upward from the horizon at sunset, the planet at these times is high in the sky and sets long after the Sun. It therefore makes a striking appearance throughout the spring months.

March

Full Moon: March 10 *New Moon:* March 25
Equinox: March 21

MERCURY is at superior conjunction on March 30, and will not be visible during the month.

VENUS is still a morning star, but now rises little more than an hour before the Sun. The planet is now moving north again, but is still far south of the Sun; at the equinox, when the Sun is on the equator, Venus is as much as 15 degrees south of it. Venus passes less than a degree north of Saturn on March 20.



Planetary Orbits in March

MARS is a brilliant evening star in the constellation Cancer; it is due south at 22^h at the beginning of the month. The planet passes north of the faint star Gamma Cancri on March 1, and reaches a stationary point on March 17 near the star cluster *Praesepe* (see diagram on page 37). This is the most northerly point of the apparent path of Mars during the year, and from this time on-

wards it moves rapidly eastwards towards *Regulus*, fading quickly as it does so. During the month the brightness decreases from magnitude −0·5 to +0·2, but even so, the planet remains brighter than *Regulus*, whose magnitude is +1·3.

JUPITER is now passing behind the Sun as seen from the Earth, and it reaches conjunction on March 16; it therefore remains invisible during the month.

SATURN now begins to appear as a morning star, moving direct in Capricornus. By the end of March it will rise in the south-east nearly two hours before the Sun. Its magnitude is +1·0, and it should not be confused with Venus, which is in the same part of the sky, but is much brighter. On March 20 and 21 the two planets will be close together in the south-eastern sky at dawn.

PLUTO is at opposition on March 2 in the eastern part of Leo. The planet is not visible to the naked eye, nor can it be seen in a small telescope, since its magnitude is about 15. The distance at opposition is about 2,990 million miles.

Eclipse seasons. Eclipses can take place only when the Earth, Sun and Moon are in a straight line, and since the orbit of the Moon is tilted at about five degrees to that of the Earth, it follows that eclipses occur only at those times when the Sun is near one of the nodes of the Moon's orbit. This orbit is twisting backwards in space, so that the nodes move westwards at the rate of about 20 degrees a year. If an eclipse takes place at one node, then suitable conditions will also occur again when the Sun has travelled nearly half-way round the sky, and has arrived at the opposite node. This will take six months – six lunar months of twenty-nine days, which is rather less than six calendar months. Thus eclipses take place at two seasons of the year about six months apart. At present the eclipse seasons are in January and July, but these dates work their way slowly backwards through the years. The Sun can never avoid being eclipsed, and there is always at least one eclipse of the Sun at each eclipse season, so that the minimum number of eclipses each year is two, and both are of the Sun. The maximum number is seven, and these may be either four of the Sun and three

of the Moon, or five of the Sun and two of the Moon. This is an unusual event, for although it happened in 1935, it will not occur again until 1982.

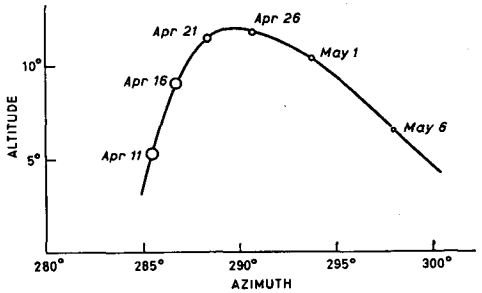
The Saros. Eclipses of the Sun and Moon repeat themselves under almost identical conditions at intervals of 18 years 11 days (or 18 years 10 days if there are five leap years in the interval). This period, known as the Saros, is said to have been used by the Chaldeans in predicting eclipses. The Saros is caused by the fact that nineteen returns of the Sun to the Moon's node (6,585·8 days) are almost exactly equal to 223 lunar months (6,585·3 days). The conditions of distance, apparent size, etc., therefore repeat themselves very exactly, although changes occur in the position of the shadow track on the Earth's surface. There will thus be a long series of similar eclipses, beginning with a small partial eclipse at one of the Earth's poles. After each successive Saros, the eclipse track moves a little farther south or north and the eclipse grows larger, and after about 150 years it becomes total. In the course of about 1,200 years the track will move right off the Earth at the other pole, and the whole series will have included about twenty partial and forty-five total solar eclipses. About seventy such series will be counted in the eighteen years of a Saros, and on the average there will be forty-one solar and twenty-nine lunar eclipses.

The eclipse of July 20 belongs to the series which gave the memorable total eclipse of 1927 June 29, which was seen under difficult weather conditions in the north of England. This series of eclipses is moving south across the Earth and is increasing in duration.

April

Full Moon: April 9 *New Moon:* April 23

MERCURY is at greatest eastern elongation on April 26 (20 degrees; evening star), and there will be an excellent opportunity to see this elusive planet under favourable conditions during the last few days of April. The diagram shows the changes in altitude and azimuth (true bearing from north through east, south and west) of Mercury on successive evenings at a time when the Sun is 6 degrees below the horizon; this will be about forty minutes after sunset at this season. The sizes of the circles give an approximate indication of the expected brightness of the planet. It will be noticed that it is brighter before the actual date of greatest elongation, but it is much more important to have a clear horizon and good visibility in order to see Mercury at all.



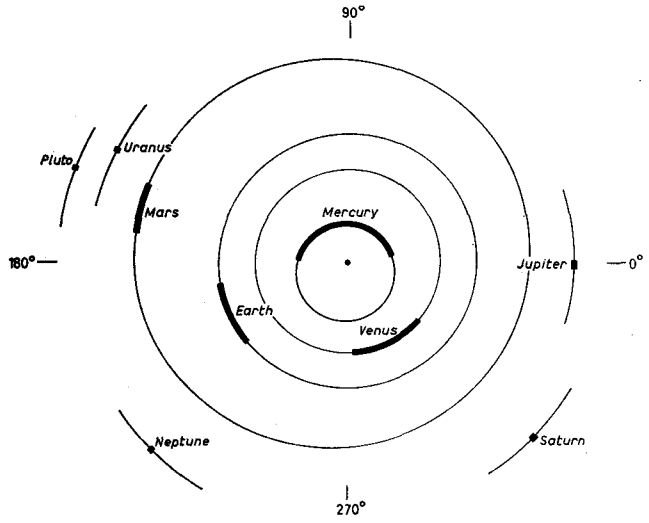
Mercury

VENUS is still theoretically a morning star, rising less than an hour before the Sun in the south-east. The planet passes less than a degree south of Jupiter on April 28, but the conjunction of these two bright objects will not be easy to see at low altitudes in the eastern sky before sunrise.

MARS is now an evening star, to be seen in the south in mid-evening. It is moving direct in Cancer, its brightness decreasing from magnitude +0·2 to +0·8 as the distance from the Earth grows rapidly greater. At the beginning of the month Mars is again quite close to the fifth magnitude star Gamma Cancri (see

diagram on page 37), this time passing south of the star, as it did in October 1962.

JUPITER now begins to appear as a morning star and at the end of April rises in the east about an hour before the Sun. The planet is quite close to Venus in the morning sky on April 28 and 29, and if the two objects are at all visible they may be distinguished by their



Planetary Orbits in April

different brightnesses, Venus (magnitude −3·4) being much brighter than Jupiter (magnitude −1·6). Jupiter crosses the equator in mid-April and so comes into the northern sky for the first time for six years.

SATURN now rises in the south-east in the early morning hours and will be seen as a bright star (magnitude +1·0), in the constellation Capricornus. Jupiter and Venus, which are both much brighter than Saturn, will be seen well to the left of that planet.

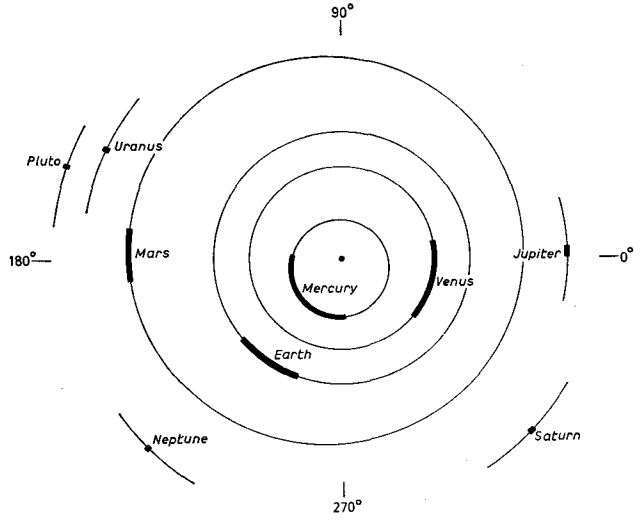
Hercules. On an April evening the golden star *Arcturus* is seen well up in the east, while the steely-blue glitter of *Vega* catches the eye as it swings up from the horizon in the north-east. Between these two bright stars lies the large constellation of Hercules, which is somewhat difficult to trace because it contains no stars brighter than the third magnitude. On a summer night Hercules is high overhead, but it may then be seen that all of its stars lie south of our zenith. In the old star atlases the figure of Hercules is drawn upside down; his foot crushes the head of the Dragon to the north, while his head is quite close to the head of Ophiuchus, who straddles the equator to the south. Now, there is no doubt that Hercules and the Dragon are two of the oldest constellations, for they figure in the sky-pictures of many of the old races of mankind. Yet it is quite unthinkable that these observers of ancient times should have drawn one of their heroes wrong way up in the sky. The explanation is, of course, that in the course of time the sky has altered, and all of these constellations have changed their positions with respect to the pole, because of the movement of the Earth's axis known as precession. To the Babylonians, nearly six thousand years ago, the Earth's pole would have pointed, not to *Polaris* as it does today, but to *Thuban*, the star Alpha in the constellation Draco. The giant Hercules would then have been closer to the pole, which in those days was closely associated with the Dragon. As a result, Hercules would have been seen north of the zenith at the highest point of his sweep across the sky, and this effect would be even more pronounced in the southerly latitude of the ancient observers. Thus at this culminating point Hercules would have appeared high in the sky, but to the north of the zenith and the right way up.

May

Full Moon: May 8 *New Moon:* May 23

MERCURY is at inferior conjunction on May 18, and will not be visible after the first few days of May (see April notes).

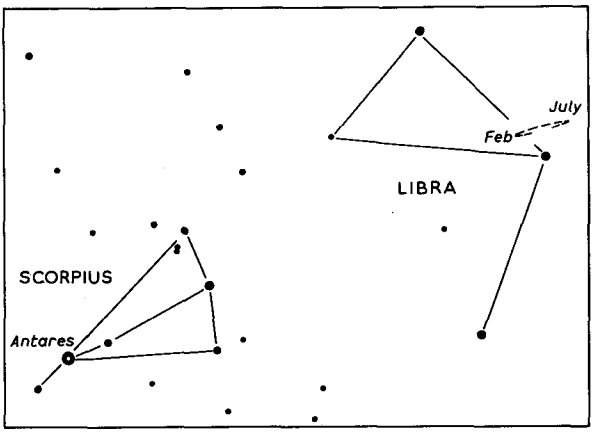
VENUS is still a morning star, rising in the east less than an hour before the Sun. The planet is now a whole magnitude fainter (—3·3) than it was at the beginning of the year, and it remains at about the same brightness for the remainder of the year.



Planetary Orbits in May

MARS is an evening star, setting in the west shortly after midnight; it is moving direct in Leo, and is now only of the first magnitude. By the end of May it is near *Regulus* again, as it was at the beginning of the year, but now planet and star are of comparable brightness (Mars, magnitude +1·2; *Regulus*, +1·3). It will be seen from the diagram on page 37 that the characteristic loop in the path of the planet is this year a particularly open one, and this arises because the Martian orbit is tilted to the ecliptic at an angle of nearly two degrees. At opposition in February the planet was

almost at its maximum distance north of the ecliptic, and it passes southwards through the ecliptic (i.e. at the descending node of the orbit) at the end of August. The changing distances and the motion of the Earth in the ecliptic exaggerate the effect of the motion of Mars as it moves north to its greatest latitude and then south to its crossing at the node.



Path of Neptune, 1963

JUPITER now rises well before the Sun and may be seen in the east in the bright dawn sky. The planet is much farther from the Sun than Venus, is higher in the sky, but not so bright (magnitude −1·6), so that there should be no possibility of confusion.

SATURN is a bright morning star in Capricornus (see diagram on page 58), and by the end of the month it rises just after midnight. Saturn grows a little brighter (magnitude +1·0 to +0·9) during the month as the distance from the Earth decreases.

NEPTUNE is at opposition on May 5, and will be found north of the third-magnitude star Alpha Librae (*Zuben el Genubi*). On the night of May 12 the planet will be approximately 1½ degrees north of the star. Neptune is not visible to the naked eye, but with a small telescope it may be seen as a greenish disc of magnitude 7·7. At opposition Neptune is at a distance from the Earth of 2,730 million miles.

Cygnus and the Galaxy. When Cygnus rises in the east on a summer evening (see chart 5) one can see why this fine group is pictured as a swan – a swan flying to the right, down the broad stream of the Milky Way, with its long neck outstretched and its wings looking surprisingly small.

The Milky Way is not uniformly bright, partly because of the many obscuring clouds of dust and gas that are found in it, and also because the Sun is not situated centrally in this great spiral nebula. The centre lies towards Scorpius and Sagittarius, while the opposite direction is in the neighbourhood of Auriga and the star *Capella*. When the Milky Way is seen on a clear dark night (and one must be well away from street lighting to see the Milky Way at its best), it is quite obvious that the part from Cygnus round to the south past *Altair* and the star-cloud of Scutum is much brighter than the rest.

Looking out towards Cygnus we are looking roughly at right-angles to the centre of the Galaxy, and the Milky Way is bright here because we are looking along one of the great spiral arms which coils away to the right in a curve through Aquila to Scorpius.

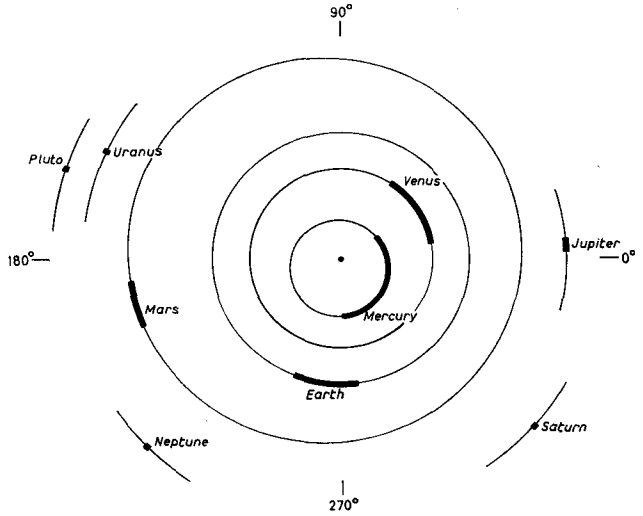
Such a system of stars cannot remain stationary, but must revolve about its centre. The Sun, like all the other stars, is revolving in this way, but our measurements of its motion depend on the objects we use for reference. If we use the nearby bright stars which are, on the whole, moving along with us, we find quite a small value which merely represents the difference between the Sun's speed and that of the stars; this is the result, often quoted, that the Sun is moving towards the constellation Hercules with a speed of about twelve miles a second. It is only when we use the more distant objects, such as the spiral nebulae, as reference points, that we get a real appreciation of the truth. We then find that the Sun is moving towards Cygnus with a speed of about 140 miles a second, in what must be an almost circular orbit about the centre of the Galaxy. At such a distance from the centre (it amounts to about 30,000 light-years) this great speed allows the Sun to do one complete revolution in about 200 million years, a period which has come to be known as a cosmic year.

June

Full Moon: June 7 *New Moon:* June 21
Solstice: June 22

MERCURY is at greatest western elongation on June 13 (23 degrees; morning star), but it is then south of the Sun and will be at a low altitude at sunrise. It is unlikely to be seen, since it is easily lost in the bright dawn sky.

VENUS is also a morning star in the same part of the sky as Mercury, but is more readily visible since it is so much brighter.



Planetary Orbits in June

The two planets are both about 20 degrees from the Sun, but there is little likelihood of confusion; if a bright planet is noticed in the east at dawn this month it is certainly Venus and not Mercury.

MARS sets at midnight in early June, its path taking it through Leo during the month. On June 1 it passes about a degree north of *Regulus*, both star and planet being of about the same brightness. On the evening of June 5, at 19^h, Mars passes rather more than half a degree (about the apparent diameter of the Sun or Moon)

north of the planet Uranus, and it should then be possible to see both planets at the same time in binoculars or a small telescope with a wide field of view.

JUPITER rises in the east shortly after midnight and is a conspicuously bright object (magnitude $-1{\cdot}9$) in a rather barren part of the sky in Pisces. The brightness of the planet and its position under the Great Square of Pegasus will make it an easy object to identify.

SATURN now rises before midnight and grows a little brighter during the month (magnitude $+0{\cdot}9$ to $+0{\cdot}7$). The planet reaches a stationary point on June 4 just north of the eastern stars of Capricornus (see diagram on page 58), and after this date it moves westwards (retrograde) as it approaches opposition.

Aberration. There is one fairly bright star that passes almost exactly overhead in the London area every day. This is the star Gamma Draconis, the brightest of four stars that form the head of the Dragon (see chart, pages 28–29). It was this star that was chosen by Bradley about the year 1725 for his attempt to determine the parallax of a star; he was unsuccessful in the attempt, but was led to make an even greater discovery, that of the aberration of light. Bradley, who later became the third Astronomer Royal, was a wonderful observer. He was one of those rare characters who never overlook the smallest detail; the great Bessel once referred to him as 'the incomparable Bradley'. As a young man he lived with his uncle, James Pound, rector of Wanstead, himself a very able amateur astronomer. Bradley followed in his footsteps, and became interested in this problem of the distances of the stars, and the determination of their parallaxes. For this purpose he measured the positions of the stars in the zenith with a zenith sector. This was a telescope (rather a crude instrument, since this was before the days of improved lenses) about 12 feet long and 3 inches aperture, suspended from its upper end, and capable of moving through a small angle which could be measured very accurately. By observing in the zenith, Bradley overcame the difficulties of mounting the instrument, and those troublesome

effects such as refraction were eliminated. In this way Bradley was able to measure the angles of certain stars from the vertical with a precision which had never before been obtained.

What Bradley had expected was that the stars would appear to move slightly as the Earth journeys from one side of its orbit to the other. But although the displacements of the stars that crossed his zenith (the brightest of these being Gamma Draconis) were certainly there, they were all at right-angles to the directions he had anticipated. They could not therefore be due to parallax, but the explanation soon came to him. If light really does travel with a definite speed, then the effects he had observed were simply due to the relation between that speed and our own speed on the moving Earth. One may compare the effect with the streaks of rain on the windows of a railway carriage. Even if the rain is falling straight down, the streaks slope across the glass, and the faster the train is moving, the more nearly horizontal do the streaks become. So the light of a star always seems to come from a point ahead of the star – it is displaced forward in the direction of the Earth's motion. Stars near the pole of the ecliptic in Draco appear to go round in small circles, those farther south move in ellipses, and those actually on the ecliptic merely oscillate in a straight line through a small angle.

This is the effect known as aberration, and in discovering it Bradley gave us not only one of our best proofs of the motion of the Earth about the Sun, but also a definite proof that light takes time to travel – a fact which was merely an interesting theory in the early eighteenth century. The fine old instrument that Bradley used is to be seen in the old Royal Observatory at Greenwich, which is now a very interesting museum.

July

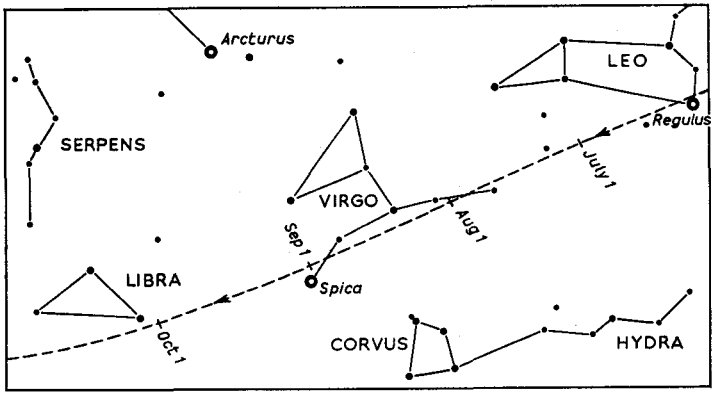
Full Moon: July 6 (with partial eclipse) *New Moon:* July 20

EARTH is at aphelion (farthest from the Sun) on July 4; its distance from the Sun at this time will be about 94,500,000 miles.

MERCURY is at superior conjunction on July 13 and will not be visible during the month.

VENUS is still a morning star, but although well north of the equator, it is now less than 10 degrees from the Sun, and is not likely to be seen as it moves towards superior conjunction.

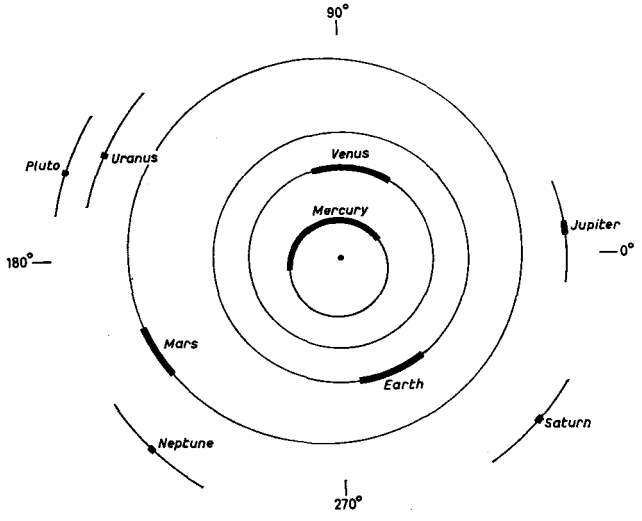
MARS sets in the west about two hours after the Sun in mid-July. The planet moves into Virgo (see diagram below) and passes south of the equator at the end of the month. It may be noticed that the planet (now only of magnitude +1·6) is far south of the crescent Moon of July 25; the differing inclinations of the two orbits are responsible for this wide divergence.



Mars, June to October, 1963

JUPITER rises in the east at midnight at the beginning of the month, and its brightness increases (magnitude −1·9 to −2·2). The direct motion of the planet becomes slower as it approaches a stationary point (see diagram on page 61).

SATURN also grows brighter (magnitude +0·7 to 0·5) as it approaches opposition. The planet is moving retrograde in Capricornus and now rises in the south-east before midnight. Saturn will be seen about two degrees north of the Moon, then three days past the Full, on the night of July 9.



Planetary Orbits in July

A partial eclipse of the Moon will take place on the night of July 6, about 70 per cent of the Moon's disk being covered by the Earth's shadow. The eclipse begins at $20^h\ 32^m$, reaches its greatest phase at $22^h\ 03^m$, and ends at $23^h\ 33^m$. The shadow will first be seen at the lower left edge of the Moon (for further details see page 72).

The total eclipse of the Sun on July 20 will be visible only in Japan, Eastern Asia and North America. In Ireland and Scotland, however, it should be possible to see the beginning of a partial eclipse of the setting Sun (see page 72).

Forgotten constellations. The part of the sky south of Cygnus and Lyra is so rich in stars that it was a temptation to many of the old astronomers to insert new constellations here. Many of these have been forgotten, and only some of those introduced by Hevelius in the seventeenth century have stood the test of popular approval. One in particular is marked by a bright patch of the Milky Way below *Altair*, the brightest star of Aquila. This patch has only a few small stars to mark its place, but it forms a noticeably bright spot in the Milky Way. It is called Scutum Sobieskii, the Shield of Sobieski, a name given by Hevelius in honour of one of Poland's heroes, King John III of the House of Sobieski. Just above Scutum, the Milky Way divides into two branches, and the right-hand branch begins with a small group of stars which was once named 'the Royal Bull of Poniatowski'. But this attempt to honour another Polish king has found no permanent place in the sky.

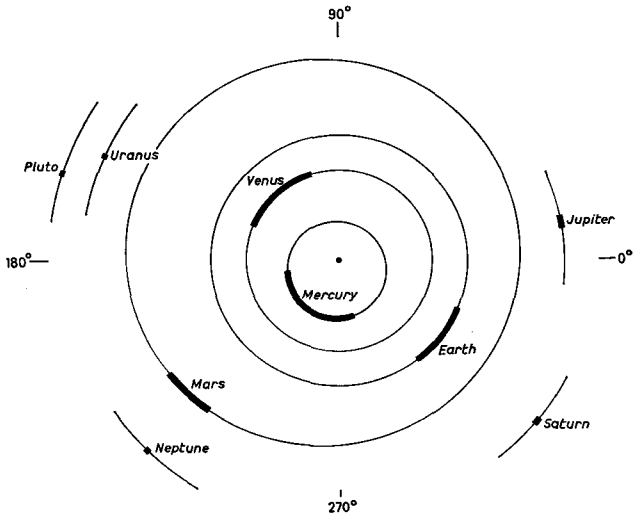
Just south of Cygnus was a group known as Vulpecula et Anser – the Fox and the Goose. The goose has gone, and only Vulpecula remains. Bode, in the eighteenth century, proposed to introduce Herschel's Telescope, an Electrical Machine, and a Printer's Workshop, and he also attempted to introduce the Honours of Frederick, a group for which he could only find room by making Andromeda draw back her arm. Lalande, who adored cats, considered this a sufficient reason for introducing a Cat among the stars, and he also tried to include a new constellation called Le Messier (that is, the Keeper, presumably of the heavenly vineyards), a name which was clearly intended as a punning allusion to Messier, the famous hunter of comets. Even in the present century there have been attempts to re-form the constellations, but all of these may be forgotten, too. The boundaries of the constellations have been fixed by international agreement, and the ancient star-figures are merely of historical interest, since they serve no useful purpose in modern astronomy.

August

Full Moon: August 5 *New Moon:* August 19

MERCURY is at greatest eastern elongation (27 degrees; evening star) on August 24. At that time, however, the planet is far south of the Sun and does not rise high enough above the horizon to avoid being lost in bright twilight sky.

VENUS, moving round the far side of its orbit, is at superior conjunction on August 30, and will not be visible during the month.



Planetary Orbits in August

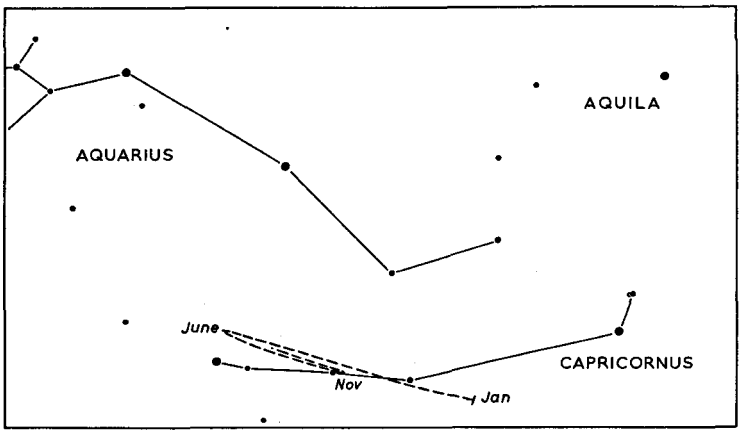
MARS now sets about two hours after the Sun and will be found in Virgo, moving towards *Spica*; it will be quite near this star at the end of the month. Of the two objects *Spica* is the brighter – *Spica* magnitude +1·2, Mars +1·7.

JUPITER now rises in the late evening and is a brilliant object (magnitude −2·2 to −2·4) in Pisces, under the left side of the Great Square of Pegasus. The planet reaches a stationary point

on August 10, and after this date begins to move westwards (retrograde). This will be a more favourable opposition of Jupiter than we have seen for many years, and the autumn months afford an ideal opportunity for studying the phenomena of the four bright satellites, which are easily seen with a small telescope.

SATURN comes to opposition on August 13, when it will be at its brightest (magnitude +0·5) and nearest to the Earth (824 million miles). The brightness of Saturn depends very largely on the angle at which the rings are seen; they were open at their widest in 1958, when the planet reached magnitude +0·3. The rings are now closing, and in 1963 are tilted at about 15 to 16 degrees, but the resulting loss of brightness is offset to some extent by the more northerly position of Saturn and its greater altitude in the sky in our latitudes. The rings and the largest satellite, Titan, may be seen in a small telescope.

Saturn will be seen about a degree north of the Full Moon on the night of August 5.



Path of Saturn, 1963

The autumn night sky. The autumn months always offer the best opportunity for the beginner to recognize the star groups, for at this time of year the sky presents much the same appearance night after night as soon as twilight ends. The reason for this is simple: the stars rise about four minutes earlier each successive night, while the Sun sets about ten minutes earlier each evening at this time of year. As a result there is only a small change in the positions of the constellations with respect to the horizon as soon as it is dark enough to see them. There is no true darkness in our latitudes from about the end of May until the end of July, but from August onwards we find that twilight ends at the following times:

August	6	end of twilight at $22^h\ 25^m$;	appropriate chart 8
	21	$21^h\ 31^m$	8
September	6	$20^h\ 40^m$	8
	21	$19^h\ 58^m$	8
October	6	$19^h\ 19^m$	8
	21	$18^h\ 47^m$	8

So on successive evenings for many weeks, as soon as it is dark, we see *Capella* and the *Pleiades* rising in the north-east, with the Plough swinging down in the north-west, while *Altair* is high in the south.

In the spring months the opposite effect occurs, for then the Sun sets *later* each evening, and this is added to the earlier time of rising of the stars, so that very rapid changes in the appearance of the sky are seen:

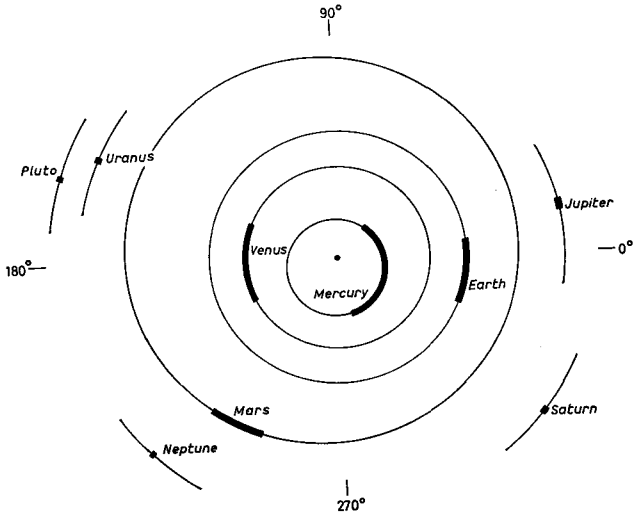
March	6	end of twilight at $17^h\ 48^m$;	appropriate chart 1
	21	$18^h\ 14^m$	1
April	6	$18^h\ 42^m$	2
	21	$19^h\ 07^m$	3
May	6	$19^h\ 33^m$	3
	21	$19^h\ 55^m$	4

September

Full Moon: September 3 *New Moon:* September 17
Equinox: September 23

MERCURY is at inferior conjunction on September 20, and will not be visible until the end of the month, when it begins to appear as a morning star (see diagram and notes on page 63).

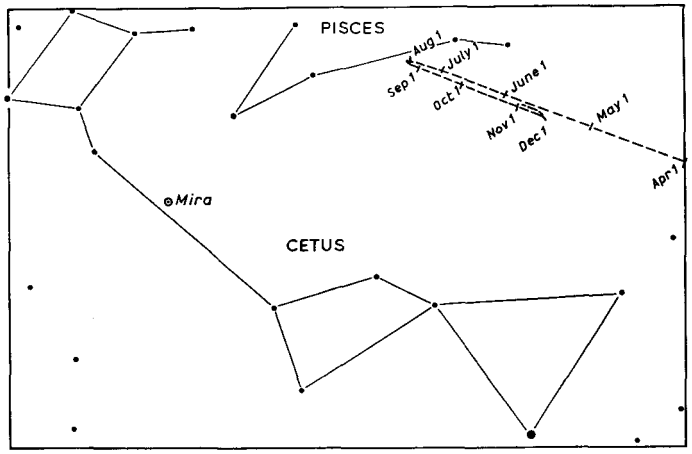
VENUS now begins very slowly to appear east of the Sun as an evening star, but even at the end of September it will be less than 10 degrees from the Sun, and is therefore unlikely to be seen.



Planetary Orbits in September

MARS is an evening star, setting less than an hour after the Sun. It passes less than 2 degrees north of *Spica* on the first of the month, and moves into Libra at the end. For the rest of the year Mars seems to keep pace with the Sun, setting each evening at about the same interval after sunset; it will, however, be difficult to obtain a glimpse of the planet, since its magnitude is now only +1·7, and it is visible for such a short interval in the south-west after sunset.

JUPITER now rises in the east in the early evening, its brightness increasing to magnitude −2·5 as it approaches opposition. This is the maximum brightness that Jupiter can attain, the planet being at perihelion on September 26, when it is 460 million miles from the Sun and 369 million miles from the Earth. At this time the north pole of Jupiter is tilted towards us, and this tilt, although small (about 2 degrees) is sufficient to allow satellite IV to escape from the planet's shadow. For this reason there are no phenomena of this satellite during the last half of the year, although the other three satellites undergo their continuous display of eclipses, transits and occultations without interruption.



Path of Jupiter, 1963

SATURN is now past opposition, and its brightness decreases a little during the month (magnitudes +0·5 to +0·7). It is an evening star, visible for most of the night in Capricornus. On the night of September 21 it will be found only about a tenth of a degree north of the fourth-magnitude star Iota Capricorni.

Wide double stars. On a September evening the star *Altair* is to be found high in the south, with Cygnus and *Vega* overhead, while below *Altair* are the two zodiacal figures of Capricornus and

Sagittarius. Capricornus is a curious animal, half goat, half fish, and this is in keeping with most of the neighbouring constellations, for these, too, are water-creatures of some kind. Very little appears to be known about the origin of Capricornus, but it is a remarkable fact that all the ancient peoples pictured a goat in this position, and even the Aztecs, far removed from eastern civilization, had a zodiac with a goat in this part of the sky. The constellation is easy to recognize, since it consists merely of a string of five or six stars turned up at the right, and in 1963, Saturn will be seen in the eastern part of this group. The uppermost of the stars at the right is Alpha Capricorni, and this is a double star; the two fairly bright stars are only a tenth of a degree apart, but are easily seen by people with normal vision.

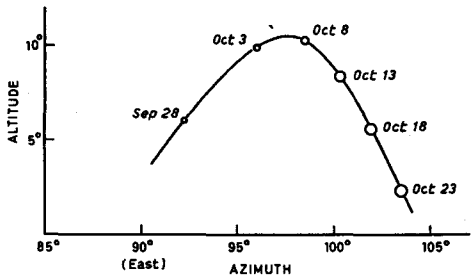
There are other naked-eye doubles in the sky – look, for example, at the stars in the *Hyades* cluster – and there is a great deal of pleasure to be found in looking for close stars and runs of stars by sweeping the sky with a pair of binoculars. For the most part these wide doubles are close together because of our point of view, for the two stars are not necessarily at the same distance from us, nor are they connected together in any way. One of the best-known doubles of this kind is formed by the star *Mizar*, the middle star in the handle of the Plough, and the little star *Alcor* which lies close beside it. Here we have two stars of very different brightness, and although they are really quite easy to see, there has always been a legend that they form a good test for keen sight. This may have been meant as sarcasm, for the Arabs had a proverb 'Show me the Moon and I will show you *Alcor*'. On the other hand, *Alcor* may have become brighter over the centuries.

A more difficult test for keen eyesight is afforded by the star Epsilon Lyrae, which is the little star just north-east of *Vega*, above and to the left of it as one faces south on a September night. This is easily seen in binoculars to consist of two stars of about equal brightnesss, but in a telescope it is seen that each star is itself a double, thus forming a quadruple system of stars.

October

Full Moon: October 3 *New Moon:* October 17

MERCURY is at greatest western elongation on October 5 (18 degrees; morning star), when it will be well placed for observation. The diagram shows the changes in altitude and azimuth of Mercury on successive mornings when the Sun is 6 degrees below the horizon; this is about half an hour before sunrise at this time of year. The changes in brightness are roughly indicated by the sizes of the circles; it will be seen that Mercury is brightest after the date of western elongation.



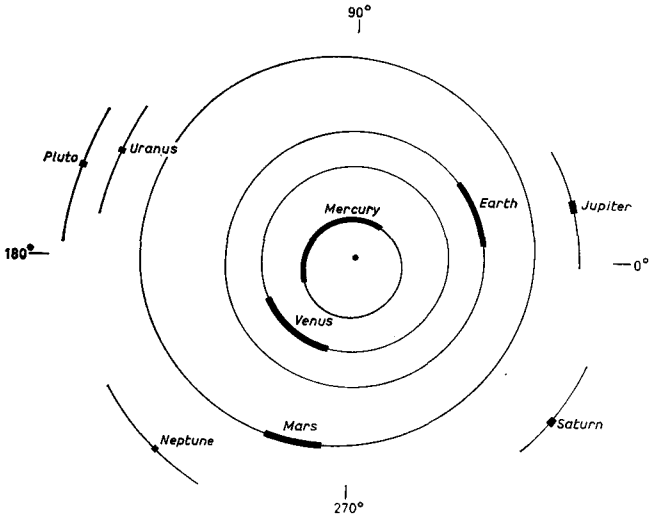
Mercury

VENUS is now theoretically an evening star, but it moves out from the Sun so slowly that by the end of the month it is only about 15 degrees from the Sun. It then sets in the south-west about half an hour after sunset.

MARS now sets about an hour after sunset; although it is more than 30 degrees from the Sun, it is far south of it, and so is very low in the south-west in the evening sky.

JUPITER is at opposition on October 8, and is then in the south at midnight. The diagram on page 61 shows its position in the constellation Pisces, north of Cetus, but the brilliance of the planet (magnitude −2·5) makes it easy to recognize. Jupiter is 368 million miles from the Earth on the date of opposition, and as it is now some degrees north of the equator it can reach as much as 40 degrees altitude at its highest point in the south at midnight.

SATURN reaches a stationary point on October 21, near the fourth-magnitude star Iota Capricorni (see diagram on page 58), and then begins to move direct (eastwards) again. The planet now sets shortly after midnight, and its brightness decreases a little during the month (magnitude +0·7 to +0·8).



Planetary Orbits in October

The Harvest Moon. Although most people regard the Full Moon of September as being the Harvest Moon, the name is more properly applied to the Full Moon nearest the equinox. This year, however, the Full Moons of September 3 and October 3 will both be seen to behave in much the same way. At a latitude of 52 degrees the Moon rises only twenty-three minutes later on successive nights at these times; the interval is reduced to about fifteen minutes at latitude 58 degrees.

The Royal Family. At midnight in October the Great Square of Pegasus is high in the south (see chart 10) and above it, almost in the zenith, is the very obvious letter W, which represents the chair in which Queen Cassiopeia is seated. To the north is her husband

Cepheus, King of Ethiopia, and one of the Argonauts who accompanied Jason on his search for the Golden Fleece. The five-sided star group which represents Cepheus is not difficult to find; it lies to the west of Cassiopeia and on the side of the pole opposite to the Plough. In this five-sided figure, the two stars farthest from the pole are Zeta and Alpha Cephei, and between them lies the little star Mu Cephei, whose remarkable colour caused Herschel to describe it as the 'garnet star' (see page 211).

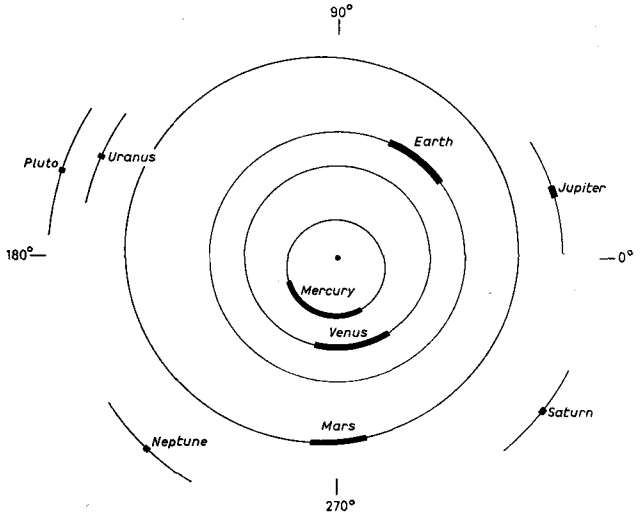
High up near the pole, the King and Queen circle for ever, for these stars never set in our latitudes. Their daughter Andromeda is there to the south, chained to the rock, waiting for Perseus to rescue her, while the sea-monster, Cetus, swims into view in the south-east. Perseus is rather a jumble of bright stars right in the heart of the Milky Way, but it is centred about its brightest star *Mirfak*. There is no resemblance to a human figure here, so one must just imagine the hero, with his upraised sword in one hand, and the head of Medusa in the other. The Gorgon's head is marked by the variable star *Algol*, while the sword handle contains the wonderful star clusters H. VI 33 and 34 (see page 199).

Andromeda is marked principally by three bright stars forming a chain from the top left corner of the Square of Pegasus eastwards to *Mirfak* in Perseus. The three stars have proper names derived from the Arabic; *Alpheratz* is Alpha Andromedae at the top left corner of the Great Square, then come *Mirach* and *Almach* to complete the chain with *Mirfak*. Of these bright stars, *Alpheratz* marks Andromeda's head, *Mirach* is at her waist, and *Almach* is her right foot. *Mirach*, the second star in the line, forms a useful guide to the Andromeda Nebula. Above *Mirach*, to the north, there are two fainter stars, the three forming Andromeda's girdle. Just above the uppermost of the three is the hazy patch of light which is the most distant object the unaided eye can look upon – the Great Nebula in Andromeda, at so great a distance that we see it, not as it is today, but as it was nearly two million years ago.

November

Full Moon: November 1 and November 30
New Moon: November 16

MERCURY is at superior conjunction on November 8 and will be too close to the Sun to be observed during the month.



Planetary Orbits in November

VENUS is an evening star, and conditions for viewing the planet slowly improve so that by the end of November, although it is still well south of the Sun, Venus will set over an hour after sunset. It will be interesting to keep a watch for the planet to determine when it can first be seen as an evening star, low in the south-west after sunset.

MARS is still an evening star and with the coming of darker skies it may be possible to catch a glimpse of the planet in the south-west after sunset. Mars moves rapidly through Scorpius and Ophiuchus into Sagittarius during the month. It is unfortunate that Mars sets so soon after the Sun, for on November 6 the planet passes north of *Antares*, and on this occasion the star,

known as the 'Rival of Mars', will really deserve its title, since it is decidedly brighter than the planet (*Antares* magnitude +1·2; Mars +1·6). Venus and Mars are close together in the sky on November 20, but the planets will have set before they are at their closest (about one twentieth of a degree apart) and will, in any case, be difficult to observe at such low altitudes.

JUPITER is in the south in mid-evening, and is still moving retrograde in Pisces; above it to the right is the Great Square of Pegasus, and below it is the large constellation Cetus. It will be noticed that the Moon passes several degrees south of Jupiter during each of its monthly journeys round the sky (October 30, November 27, December 24).

SATURN is now moving direct again in Capricornus. By the end of the month it sets in mid-evening in the south-west, and its brightness will have still further diminished (magnitude +0·8 to +0·9).

Both Full Moons of November are almost at perigee, at a distance of about 222,000 miles. This may be contrasted with the Full Moon of April 9, which was almost at apogee (252,000 miles). Since there is a difference of 30,000 miles in these figures, the Full Moons of November should appear larger than usual, but the effect is generally hidden by illusions of size, which make it difficult for the eye to appreciate the real changes that take place from month to month.

The Zodiac. On these winter evenings, with the ecliptic high in the sky, it is possible to see half of the zodiacal constellations at one time. The zodiac is the broad belt, extending for about 8 degrees on either side of the ecliptic, in which the Sun, Moon, and planets are always to be seen. Originally the zodiac was divided into twelve 'signs' each measuring 30 degrees of longitude, with which were associated appropriate constellations. Because of precession, the signs have moved away from their original positions, but the twelve zodiacal constellations, with all their historical interest, remain. Their names may be remembered by the little verse written two centuries ago by Isaac Watts, who also gave us many

of our best-known hymns, including 'O God our help in ages past'. He also wrote a great deal of highly moral verse for young people, and although this was not always so successful as his hymns, we still find traces of it here and there. It was his poem 'How doth the little busy bee' which Alice tried to recite to the Gryphon with such curious results, while such lines as 'Satan finds some mischief still for idle hands to do', and 'Birds in their little nests agree' are almost regarded as proverbs today. But astronomers owe a debt of gratitude to Watts for his little effort about the Zodiac, for it is at least in the English language, although it is not often quoted correctly:

The Ram, the Bull, the Heavenly Twins,
Beneath the Crab the Lion shines,
The Virgin and the Scales.
The Scorpion, Archer and He-Goat,
The Man that pours the Water out,
And Fish with glittering tails.

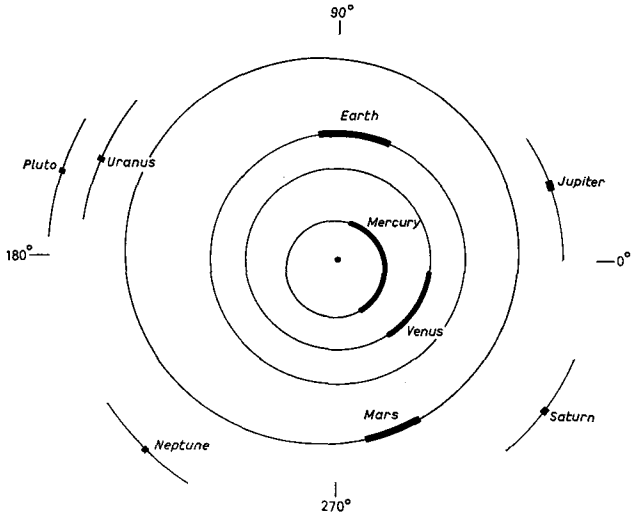
Aquarius and the Fishes. Below the Great Square of Pegasus is the rather uninteresting group of faint stars that form the constellation of Pisces the Fishes. There are two fishes, joined together on the old star-maps by a long ribbon, and they call to mind the fable of Venus and Cupid, who, frightened by the giant Typhon, threw themselves into the river, where they were changed into fishes. To the west of Pisces is the large constellation Aquarius, 'the Man that pours the Water out'. The stars of this group are not very bright, but they mark the place which the Sun used to occupy in the rainy season in the Mediterranean area, so the old nations of that region used the figure of a man pouring water out of an urn to represent the fact. The water runs out in a stream to the south and enters the mouth of a third fish, Piscis Austrinus, the Southern Fish, whose brightest star is *Fomalhaut*. This star, which is thirty degrees south of the equator, and therefore very low in the sky in this country, may be seen in the south below Aquarius and the Square of Pegasus on any clear autumn evening.

December

New Moon: December 16 *Full Moon:* December 30
Solstice: December 22

MERCURY is at greatest eastern elongation on December 18 (20 degrees; evening star), but the planet is south of the Sun and is not likely to be seen.

VENUS reaches its most southerly declination at the beginning of the month, and as it begins to move north again it becomes more readily visible as an evening star in the south-west at sunset; by the end of December it sets two hours after the Sun. This marks the beginning of a very favourable apparition of Venus, which will come to greatest eastern elongation in April 1964, and will be a splendid object in the evening sky throughout the spring months.



Planetary Orbits in December

MARS is unlikely to be seen this month as it sets shortly after the Sun. It is still (in theory) an evening star, but is now drawing rapidly in to the Sun to reach conjunction in February 1964. The next opposition of Mars occurs in March 1965.

JUPITER reaches a stationary point on December 6 and then begins to move to the east again (see diagram on page 61). The planet is now rather less bright than it was at opposition (magnitude −2·1), but it is still a brilliant object in the south-west in the evening sky, setting at midnight at the end of the year. In 1964 Jupiter will be at opposition in November, and will be very favourably placed on the borders of Aries and Taurus, near the star cluster known as the *Pleiades*.

SATURN sets in the south-west in the early evening, appearing as a first-magnitude star in Capricornus. In 1964 the planet moves forward into Aquarius, where opposition takes place at the end of August.

The total eclipse of the Moon on December 30 is not visible in the British Isles; it takes place at midday, G.M.T., and is therefore only visible on the other side of the Earth, i.e. in parts of North America, the Pacific Ocean and Australasia.

Albedo. Changes in the brightness of Jupiter depend mainly on its distance from the Sun and from the Earth, but this planet is so far away that variations in distance make little difference, and Jupiter is always a brilliant object. In the case of Mars, however, there are much greater variations, for this planet can come within 35 million miles of the Earth, and at such times can even outshine Jupiter. There are also variations in the brightness of Saturn, in spite of its great distance, but here it is the inclination of the rings which causes the change, and Saturn can be three times as bright when the rings are wide open as it is when they are seen edge-on. Venus is the brightest of all the planets, mainly because it is nearer the Sun, but in this case there is the additional complication that this planet can show a complete range of phases, from zero illumination when it is nearest at inferior conjunction, to full illumination when it is farthest away at superior conjunction. The two effects of distance and phase work against each other, and Venus is actually brightest when it is in the crescent phase.

To compare one planet with another, however, we must also take into account the nature of the surface in each case. The

amount of sunlight falling on each planet is easily calculated, and when this is compared with the amount sent back to us from the planet's surface, we can measure the albedo of the planet—this is the percentage of the sunlight which its surface scatters in all directions. Now, even a black object will scatter a certain amount of light, but in the case of Venus the albedo is 76 per cent, an astonishingly high figure, for not even fresh snow can approach this. A complete covering of high cloud is the only possible explanation, and similar, but smaller, high figures have also been given for Jupiter, Saturn, Uranus and Neptune. At the other end of the scale, Mars has an albedo of 15 per cent, while Mercury and our Moon scatter only 7 per cent of the sunlight falling on them. It is even possible to give a figure for the Earth's albedo from astronomical observations, although this is certain to be improved when observations from space-craft can be utilized for this purpose. In the spring months when the young crescent Moon is high in the sky at sunset, one can observe the beautiful phenomenon of the earthlight on the Moon, known as 'the old Moon in the young Moon's arms'. (The phenomenon is also visible with the waning crescent moon on autumn mornings, but this does not seem to have received such a poetic description!) On these occasions the part of the Moon which is normally invisible is faintly illuminated, and the whole circle of the Moon can be seen. At this time the Earth would appear almost Full to an observer on the Moon, and it is the bright earthlight that we can see, and, of course, measure. It is thus found that the Earth gives as much as eighty times as much light to the Moon as the Full Moon gives to us, and knowing the sizes of the two bodies, we can calculate that the albedo of the Earth is about 35 per cent.

Eclipses, 1963

In 1963 there will be four eclipses, two of the Sun and two of the Moon, and in addition, there is a penumbral eclipse of the Moon. Of these, only the lunar eclipse of July 6 is visible in this country, although the beginning of the eclipse of the Sun on July 20 may be visible in Scotland and northern Ireland.

1. *An annular eclipse of the Sun* on January 25 will be visible along a track from southern South America across the South Atlantic Ocean to the tip of South Africa, ending east of Madagascar. The eclipse is of short duration.
2. *A partial eclipse of the Moon* on July 6 begins at $20^h\ 32^m$, when the shadow of the Earth will first be seen on the lower left of the face of the Full Moon, which will be very low in the south-east at the time. The shadow passes slowly to the right, reaching a maximum at $22^h\ 03^m$, when 71 per cent of the Moon's disk will be darkened. The shadow passes off the right lower edge of the Moon at $23^h\ 33^m$.
3. *A total eclipse of the Sun* on July 20 will be seen in Japan, the northern Pacific Ocean, Alaska and Canada. It will be visible as a partial eclipse over a wide area, and the sunset boundary of this area just covers the greater part of Ireland and Scotland. It may therefore be possible to see the beginning of this eclipse for a few minutes just before sunset, particularly in the more northerly regions of these two countries.
4. *A total eclipse of the Moon* on December 30 takes place at about 11^h, and is therefore not visible in this country. It will be seen only on the night-side of the Earth, in North America, the Pacific Ocean, Australasia, etc.

The penumbral eclipse of the Moon on January 9 begins at $21^h\ 04^m$ and reaches its maximum at $23^h\ 19^m$, but the change in the Moon's light is very small, and these penumbral eclipses are not readily observed.

Occultations

In the course of its journey round the sky each month, the Moon passes in front of all the stars in its path, and the timing of these occultations is useful in fixing the position and motion of the Moon. The Moon's orbit is tilted at more than 5 degrees to the ecliptic, but it is not fixed in space. It twists steadily westwards at the rate of about 20 degrees a year, a complete revolution taking 18·6 years, during which time all the stars that lie within about $6\frac{1}{2}$ degrees of the ecliptic will be occulted. The occultations of any one star continue month after month until the Moon's path has twisted away from the star, but only a few of these occultations will be visible at any one place in hours of darkness.

There are only four first-magnitude stars that can be occulted by the Moon; these are *Regulus*, *Aldebaran*, *Spica* and *Antares*. In 1963, however, the Moon's path is in such a position that it passes north of all four stars, and they cannot therefore be occulted.

The planets Mercury, Venus, Mars and Saturn are all occulted by the Moon during 1963, but in this country only the occultation of Venus on December 18 is likely to be observed, and as this occurs in daylight in the afternoon (the Moon being then only $2\frac{1}{2}$ days old) the event is only likely to be seen by those possessing suitable instruments.

Details of occultations of the planets, and of all stars down to magnitude 7·5, as well as possible occultations of stars by planets, are published in the annual *Handbook* of the British Astronomical Association.

Comets in 1963

The appearance of a bright comet is a rare event which can never be predicted in advance, because this class of object travels round the sun in an enormous orbit with a period which may well be many thousands of years. There are therefore no records of the previous appearances of these bodies, and we are unable to follow

their wanderings through space. The comets of short period, on the other hand, return at regular intervals, and attract a good deal of attention. Unfortunately they are all faint objects, and are recovered and followed by photographic methods, using large telescopes. Most of these short-period comets travel in orbits which carry them out to the orbit of Jupiter, and it is this planet which is responsible for the severe perturbations which many of these comets undergo. In 1963 the following short-period comets are expected to return to perihelion:

Comet Whipple has a period of 7·4 years, and a small eccentricity of 0·36. It has been seen at each of its returns since its discovery in 1933, and is expected at perihelion in the spring of 1963.

Comet Johnson was found in 1949, and was also seen in 1956. It has a period of 6·9 years and a small eccentricity similar to that of Comet Whipple.

Comet Ashbrook-Jackson, discovered in 1948 and seen again in 1956, is expected to return in the autumn of 1963. It has a period of 7·5 years, and is another comet with small eccentricity.

Comet d'Arrest is one of the older comets, having been discovered in 1851. It has been seen at ten returns, but was missed in 1957. The period of this comet is 6·7 years, but it has the much larger eccentricity of 0·61.

Comet Daniel, which should return to the Sun at the end of 1963, was also missed in 1957. First seen in 1909, it has a period of 6·7 years and the rather high inclination of 20 degrees.

Comet Pons-Winnecke, which is not due at perihelion until the the beginning of 1964, will, it is hoped, be recovered during this year, since it was not seen at its last return in 1957 (which was clearly a bad year for comet recovery!). This comet, discovered by Pons in 1819, was next found by Winnecke in 1858, and since then has been seen at thirteen returns, the last being in 1951. The period of this comet was originally 5·6 years, so that it made close approaches to Jupiter at each alternate revolution. The resulting perturbations have made the orbit larger and less eccentric, and the period is now 6·2 years, while the inclination to the ecliptic has increased from 11 to 22 degrees.

Comets Schwassmann-Wachmann (*1*) and *Oterma* are visible every year because they travel round the Sun in orbits which are much more nearly circular than those of most other comets. Comet Schwassmann-Wachmann has an orbit with a period of sixteen years which lies entirely between the orbits of Jupiter and Saturn. It undergoes remarkable changes of brightness, which seem to have some connexion with solar activity. Comet Oterma has a smaller orbit, lying between those of Mars and Jupiter, and resembling the orbits of certain minor planets. The period at present is nearly eight years, but Miss L. Oterma has shown that the comet will make a close approach to Jupiter in 1962–64, and this will cause the orbit to become much larger and more eccentric, with a period of nineteen years. As a result the comet will only be visible in large telescopes in future years, because its perihelion distance will have increased from 3·4 to 5·3 astronomical units.

Meteors

Meteors ('shooting stars') may be seen on any clear moonless night, but on certain nights of the year their number increases noticeably. This occurs when the Earth chances to intersect the orbit of a meteor swarm, which is a concentration of meteoric dust moving in an orbit around the Sun. Such an intersection can occur only at one particular time of year, but if the dust is spread out along the orbit, the resulting shower of meteors may last for several days. The word 'shower' must not be misinterpreted – only on very rare occasions have the meteors fallen so fast as to resemble snowflakes falling.

The naked-eye study of meteors is quite a laborious task, but even a casual observer, watching for, say, ten minutes on an August night, may observe a number of Perseids. If their tracks are marked on a star map, and traced backwards, a number of them will be found to intersect in a point (or a small area of the sky) which marks the radiant of the shower. This gives the direction from which the meteors have come.

The following table gives some of the more easily observed showers, with their radiants; the effect of moonlight in 1963 is indicated.

Limiting dates	*Shower*	*Maximum*	*R.A.*	*Dec.*	*Notes*
Jan. 3–4	Quadrantids	Jan. 3	$15^h\ 28^m$	$+50°$	
April 20–22	Lyrids	April 22	$18^h\ 04^m$	$+33°$	
July 27–Aug. 17	Perseids	Aug. 12	$3^h\ 04^m$	$+58°$	
Oct. 15–25	Orionids	Oct. 20–21	$6^h\ 24^m$	$+15°$	
Oct. 26–Nov. 16	Taurids	Nov. 1–7	$3^h\ 36^m$	$+14°$	M
Nov. 15–17	Leonids	Nov. 16	$10^h\ 08^m$	$+22°$	
Dec. 9–14	Geminids	Dec. 13	$7^h\ 28^m$	$+32°$	
Dec. 20–22	Ursids	Dec. 22	$14^h\ 28^m$	$+76°$	

M=moonlight interferes

Minor Planets in 1963

Of the 1,600 minor planets which are listed in the catalogues, only the 'big four', Ceres, Pallas, Juno and Vesta, can reach any considerable brightness, and only the last of these, Vesta, can occasionally be seen with the naked eye. This may happen in 1963 at the time of opposition on March 21; Vesta is then in Leo, and on the night of March 24 it will pass about half a degree south of *Denebola* (Beta Leonis) in the tail of the Lion.

The planets Ceres and Juno are also in Leo, although they are both far below naked-eye brightness, and both come to opposition in March. As an indication of the very different inclinations of the orbits of these small planets, it may be noted that at the time of opposition Ceres is well north of Delta Leonis, while Juno is in the south of this constellation, only a few degrees north of the equator.

Some Events of 1964

ECLIPSES

In 1964 there will be six eclipses, four of the Sun and two of the Moon.

Jan. 14 – a partial eclipse of the Sun, visible only in south polar regions, and in the south of South America.

June 10 – a partial eclipse of the Sun, visible in Australia.

June 25 – a total eclipse of the Moon, visible in Gt. Britain.

July 9 – a partial eclipse of the Sun, visible in the Arctic, and in northern Asia and Canada.

Dec. 3–4 – a partial eclipse of the Sun, visible only in regions bordering the north Pacific Ocean.

Dec. 19 – a total eclipse of the Moon, visible in Gt. Britain.

THE PLANETS

Mercury may best be seen as an evening star at eastern elongation on April 7, and as a morning star at western elongation on September 18.

Venus will be a splendid object as an evening star throughout the spring months (greatest elongation April 10), and after inferior conjunction on June 19 it will be a brilliant morning star (greatest western elongation August 29).

Mars will be in conjunction with the Sun in February and will begin to appear as a morning star in the second half of the year.

Jupiter will be in conjunction on April 22, and at opposition on November 13, when it will be seen on the borders of Aries and Taurus.

Saturn will be in conjunction on February 15, and at opposition on August 24 in Aquarius.

Uranus will be at opposition on February 27, and *Pluto* on March 3, both planets being still in Leo; *Neptune* is at opposition on May 7 in Libra.

The minor planet *Vesta* may reach magnitude 6 at opposition on September 2 in Aquarius.

Eyepieces - A Practical Assessment

H. E. DALL

The number and variety of eyepieces met with in optical instruments or described in the literature and in advertisements is so large that the non-specialist may be excused for feeling confused and in need of advice on their choice and use.

The first part of this article deals with general characteristics of available types, while the second part discusses merits and demerits of specific types for astronomical purposes.

With the exception of the relatively rare Galilean negative lens eyepiece, the function of all is to magnify the real image formed by the object-glass, mirror, or other image-forming system, and present to the eye a bundle of rays covering a fair angle, and in a condition to be refocused easily and clearly on the retina.

It is axiomatic that no optical system is perfect, and a compromise is always involved both in the design and in the choice for any duty.

Desirable and undesirable features which are involved in the compromise are:

1. Cost of materials and manufacture.
2. Angle of field of acceptable definition.
3. Eye clearance.
4. Correction or tolerance of optical errors which vitiate performance, e.g. spherical and chromatic aberration, coma, astigmatism, distortion, ghosts and flare.
5. Loss of light in transmission.
6. Ease of cleaning the important surfaces without damage.
7. Suitability for projection.

Dealing with each of these features in order:

1. *Cost.* The fewer the elements, the lower the cost, and if the elements are identical and of low-cost glass, so much the better from this one point of view. The most expensive types have six or seven elements with several different types of glass of varying degrees of hardness and stability. These complex types are usually designed for wide fields and low focal ratio, and are correspondingly bulky and heavy. If used with high focal ratio instruments, they may be much inferior to the simple two-element types. High focal ratio may be exemplified by the normal astronomical refractor with focal length twelve to eighteen times the aperture (f.12 to f.18), or by a Cassegrain telescope with a final equivalent focus not less than twelve times the primary aperture; or by any telescope which has its primary focal length increased to this extent by the use of a Barlow lens or by a positive erector or transfer lens. For these types of telescope the simple Huyghenian performs admirably. The somewhat simpler Ramsden type is not so good because of false colour away from the centre of the field.

A more expensive eyepiece is advisable for telescopes of lesser focal ratio than f.8, and the choice should be made by the user after considering the factors which rate importantly for the individual.

The Huyghenian can still be used with satisfaction in the range f.8 to f.12, particularly if the mirror or object glass is fully or slightly overcorrected for spherical aberration under normal conditions of use. During evening observation with falling temperature, mirrors are frequently overcorrected, and these are occasions when a Huyghenian may well define better than an expensive eyepiece, even when working at f.7.

2. *Angle of Field.* When comparing eyepieces, it is the *apparent* angle of field that is important. This is the angle through which the eye moves between an examination of the top and bottom (or right and left) edge of the visible field of view.

Angles less than 35° are considered narrow. Between 35° and 45° are medium, and 45° to 60° are wide, while angles between 60° and 80° give an 'extra' wide field. In no type of eyepiece is definition at the edge of the field as good as in the centre, but for extra

wide fields the fall in definition at the edge is more evident. This fall, unless obviously bad, is not particularly serious, because any part of the image which is to be scrutinized carefully should be brought into the central region. The wide field is useful for searching purposes or for spectacular views of star clusters, or for viewing the entire Moon with powers of $\times 100$ to $\times 140$. For variable star work it is essential to avoid the outfield area, where aberrations and cut-off may seriously degrade the illumination.

The great bulk of astronomical observation is carried out with medium field eyepieces.

3. *Eye Clearance* is the distance between the outer surface of the eye lens and the Ramsden disc, exit pupil, or eyebeam. This is the real image of the object-glass or mirror formed by the eyepiece. It is at this point that the various parallel bundles of rays from all parts of the field converge, and it is here that the iris of the eye should be placed if the whole field is to be visible at once. There is little benefit from a wide or even a medium field eyepiece if the eye clearance is too small or if an eyecap prevents the eye from reaching it. For a spectacle wearer (with astigmatism) a minimum effective clearance of $\frac{5}{8}$ inch is desirable. Without spectacles half this distance suffices, although a greater distance reduces the risk of 'steaming up' of the lens in cold weather. If the iris cannot reach the eyebeam, only part of the field is visible at one view and the eye must be moved about to complete the exploration of the field. This is particularly undesirable for binoculars, yet many are so badly designed that although the field may be about 70°, only half this is visible without moving the eye. The eye clearance is rarely more than 80 per cent of the focal length of the eyepiece, and often it is much less, hence no eyepiece with a focal length under $\frac{3}{4}$ inch will give a medium or wide field without eye movement for spectacle wearers, or half this for non-spectacle wearers. It follows from this that short focal length eyepieces can be used with comfort only if small fields of view, e.g. 30°, are acceptable.

Some observers prefer small fields, particularly if a clock drive permits them to keep the objects near the centre of the field without effort; for planetary or double star work a narrow field is thus

no handicap. On the other hand, an observer who feels the need of a comfortable and extensive view, e.g. of nebulae or clusters, is strongly advised to use eyepieces not less than $\frac{3}{4}$ inch focus and used in conjunction with a Barlow lens if necessary to give adequate power. To avoid bad 'cut-off' of illumination at the edge of wide fields it is also necessary to have an eye lens of diameter approximating to the focal length.

Too great an eye clearance is not common, but it can happen with uncapped low-power eyepieces, and results in 'shadowing' of the field until the eye is withdrawn to the exit pupil, an action almost automatic for a trained eye. An unpleasant form of shadowing of the field which cannot be cured by eye movement is that caused by severe spherical aberration of the eyepiece in the reverse direction, i.e. in the direction of the real image formation at the eyebeam.

Instead of a single position for the eyebeam, various images from different parts of the field are strung along the optical axis and the iris cannot accept them all at once if the power is low. If a 'sky flood' stop is placed at the eyebeam, as was done in the old speculum-metal Gregorians, only small fields are possible because of this defect and the interference with the best eye position.

4. *Errors.* As already mentioned, simple eyepieces of the one- or two-element types can give quite acceptable definition when working with telescopes with focal ratios greater than f.8.

For f.4 to f.6 a more complex type of eyepiece with from three to six elements is necessary to achieve a good standard of definition over a medium or wide field. The important axial errors are spherical and chromatic aberration; these should ideally be corrected taking into account the errors of the objective system with any prisms in the path, also the chromatic errors of the eye. In practice an ideal correction is rarely achieved, but it is sufficient if the combined errors midfield do not result in a blur exceeding 1–1$\frac{1}{2}$ minutes of arc across – say 1/2000 of the field of view. This standard is not easy to achieve with wide-field eyepieces working at f.4, but it is reasonably easy at the other end of the focal ratio

range. It cannot be achieved towards the edge of the field because of outfield errors; principally coma, astigmatism, and chromatic differences or magnification. Curvature of field also becomes of importance, but can be focused out, whereas the other outfield errors, which give rise to star images of weird shapes, cannot be improved by refocusing. Assuming that it is desired to use a wide-field eyepiece on a well-corrected Newtonian or Catadioptric for comet seeking or similar duties, the gain in illumination by using an f.3 primary image may be more than offset by outfield blurring when compared with an f.4 primary image. For more usual astronomical duties a three- or four-element eyepiece will enable a medium field to be covered with acceptable definition for primary images not less than f.5. The presence of ghosts or flares arising from internal reflections is almost inevitable for five- and six-element types and is sometimes seen even with those with only two elements. It can result in false satellites to Jupiter or spurious companions to bright stars; these will not mislead an experienced observer, who will note relative movements when rotating the eyepiece or moving the telescope.

Efficient lens coating (blooming) of all lens surfaces, except that next to the eye, will greatly reduce or even eliminate trouble with ghosts, quite apart from adding materially to the illumination. The gain is only 7 per cent or so for the usual two-element types, but can amount to 20 per cent for six-element types, thus offsetting most of the loss arising from the extra elements. It is not advisable to bloom the surface next to the eye, because it may have to be wiped free of condensation frequently, and even hard-coated surfaces suffer from this treatment.

Distortion in an eyepiece is due to magnification varying over the field, but is not an important defect except where measurements (e.g. of photographs taken by projection) are required.

5. *Loss of light* in transmission through the eyepiece is inevitably greatest with complex types, but as already mentioned, much of the loss can be offset by efficient lens coating. The greater vulnerability of the coated surfaces to scratches during cleaning operations must always be borne in mind, and they should be

treated gently. When not coated, the loss of light occurs at every air-glass surface by reflection. Other and much smaller losses arise from reflection at cemented surfaces and by absorption in the glass. The reflection loss per air/glass surface is slightly over 4 per cent for crown glass and about 6 per cent for dense flint and dense barium crown. Glasses of the two latter types acquire a natural bloom with age, due to leaching out of the lead and barium in the surface layers in humid atmospheres. This natural stain is sometimes beneficial, but eventually the outer surface weathers to a scattering layer of an undesirable kind.

Loss of light by absorption does not usually exceed 1 per cent per element except when cheap green glass is used.

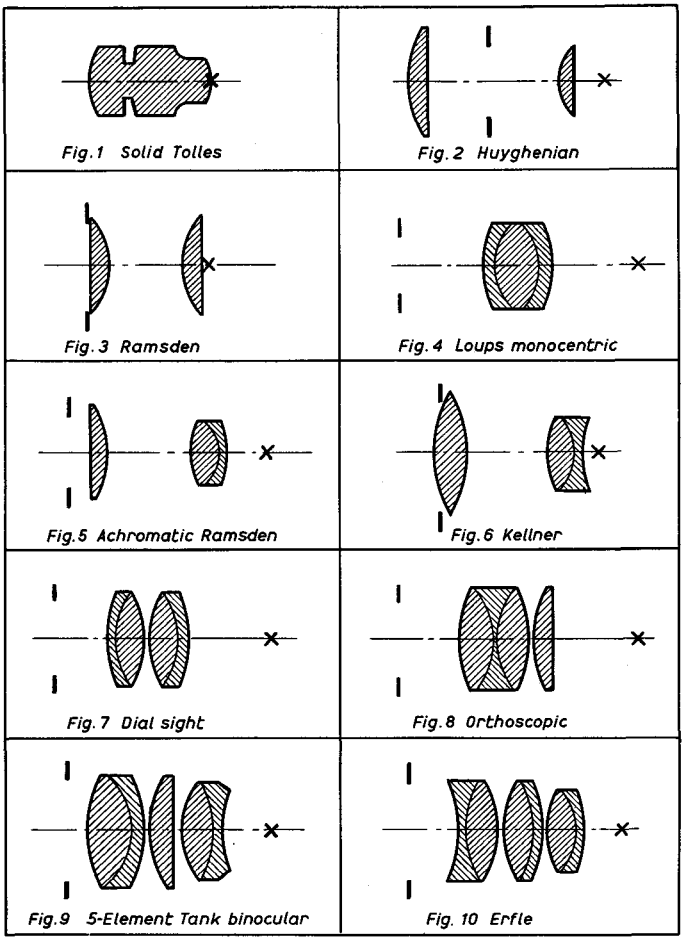
Typical figures for overall loss of light are:

Single element type:	loss	9% uncoated
		6½% coated 1 surface
2-element type:		17% uncoated
		10% coated 3 surfaces
3-element (4-glass/air):		19% uncoated
		11% coated 3 surfaces
4-element (4-glass/air):		21% uncoated
		12% coated 3 surfaces
5-element (6-glass/air):		28% uncoated
		15% coated 5 surfaces
6-element (6-glass/air)		30% uncoated
		16% coated 5 surfaces

The gain from coating in the last item is between a transmission of 70 and 84 per cent. This is a 20 per cent gain in light.

6. *Accessibility* of the elements for cleaning purposes is quite worth consideration in assessing the merits of an eyepiece. In particular the surface next to the eye should not be shrouded with an eyecap which would prevent a cross wipe with a grit- and grease-free soft handkerchief. The outside field surface is also liable to collect dust, and should be easily accessible for cleaning, but must never project beyond the cell ring or other protective part of the mount. The inner surfaces may need attention at, say,

yearly intervals and again should be easily dismounted. Permanent burnishing in of elements preventing dismounting should be condemned.



Ten Basic forms of Eyepiece with positions of Field Stop and eyepoint
Eyepieces (H. E. Dall)

7. *Projection.* In general the three- to six-element achromatized types are most suitable for photography by projection through the eyepiece. The simpler Huyghenian, if correctly made, does not show colour fringes when used visually, because the red and blue virtual images are seen of equal size. When this eyepiece is used for projection purposes, however, colour fringes are much in evidence, and colour filters are desirable to obtain good images.

Descriptions of Specific Types

Figs. 1–10 illustrate the form and relationship of the optical elements in all the more commonly used eyepieces. Detailed comment on each follows; they are given in order of increasing complexity. Herschel used many single-element crown-glass biconvex eyepieces, especially for high powers, but as the field of good definition of these is barely 10°, they make no appeal to modern amateur or professional astronomers.

Fig. 1 shows the single-element Tolles form, sometimes called solid Huyghenian. It has considerable merits in giving high light transmission and no ghosts. The spherical aberration is less than 20 per cent of that of a normal Huyghenian. The image is crisp and colour-free even for f.6 telescopes. The disadvantages are, however, severe. There is considerable field curvature and no eye clearance. The field is 28°–30°, but the effective field without eye movement is little more than 20°. The focal plane is internal and a groove in this plane forms a field stop. If this is omitted (or indeed from any eyepiece) a blurred edge to the field of view results, which psychologically is not so satisfying as a sharp boundary. The Tolles solid lens has been made from hard crown and barium crown glass. The best ratio and separation of the curves varies with the glass used. To observers who do not object to the close eyepoint and small field it is excellent for planetary observation and for double stars.

An achromatic version has an eyecap of dense flint glass cemented on. This version has a greater eye clearance and field and an external focus – an improvement, but more expensive and putting it into the class of Fig. 4.

Fig. 2 is the common Huyghenian, one of the oldest forms and well suited for long focal ratios. It is probably more used in optical instruments than any other kind, the majority being for microscopes, where the focal ratio varies from f.15 to f.50. Its limitations have already been discussed, but its merits have often been vitiated by poor design and manufacture, such as by the use of poor non-optical glass and bad centring, as well as wrong separation. The textbook 3 to 1 ratio of foci of the elements results in a small eye clearance, and a better compromise is a ratio of 2 : 1, with a separation half the sum of the foci. For a 1-inch focus eyepiece this means elements of $1\frac{1}{2}$ inch and $\frac{3}{4}$ inch focus, with an eye clearance of about 30 per cent of the focal length. Both elements are normally plano-convex and of inexpensive crown glass which is durable and not easily scratched. The field stop between the elements is in the focus of the eye lens and has a diameter of a little over half the focus of the eyepiece.

The spherical aberration of the Huyghenian is large, and amounts to about 3 per cent of the focal length for f.10, varying inversely as the square of the focal ratio; hence the warning against their use on small ratios. The field is 40°–45°. It gives no outfield colour and little field curvature. It is sometimes described as a negative eyepiece because it cannot be used as a magnifier, with its internal focus. By departing from the plano-convex form for the elements, variants have been made with slightly improved performance and field, but these are little used today. Another variant with a cemented achromat eye lens is much better for projection purposes, and there is a form of projecting eyepiece for microscopy of this design.

Fig. 3 is the common Ramsden eyepiece. The textbook form, consisting of two identical plano-convex lenses of crown glass separated by a distance equal to their focus, suffers from zero eye clearance and in having the field lens in focus together with any dust on its surface. In addition there is a great deal of outfield false colour. The first two defects are reduced by making the separation about 70 per cent of the focal length, which is a fairly common practice. This gives an eye clearance of about 20 per cent,

not sufficient to enable the field of 40° – 45° to be seen without some eye movement. The spherical aberration of the Ramsden is much less than that of the Huyghenian, and it can be used down to about f.6 in short foci.

The fold stop is just outside the lens, and the type has been much used for micrometers and surveying instruments which have cross wires coincident with the primary image. For non-spectacle wearers the close eyepoint is less inconvenient, and the outfield colour can be made use of to counteract atmospheric dispersion to some extent for low-altitude astronomical objects. Observers with short sight (myopia) find they still focus dust on the field lens too easily, and get more satisfaction from the Huyghenian, with which this does not occur. The Ramsden is the cheapest two-element type to produce, and is used in America to a much greater extent than in England.

Fig. 4. A cemented Triplet, which has been considerably favoured for its crisp images and economy of light, is the monocentric or its equally satisfactory variant, the 'Loups' triplet. In the former all the six curves are struck from the same point, the centre lens being of crown glass – near spherical; the two outer lenses are of dense flint – relatively soft. With the concentric design, centring of the components becomes of minor importance, but little if any other advantages accrue, and it is noteworthy that many pre-war Zeiss Monocentrics did not follow this design, but were of the 'Loups' type as shown in the figure. With only two air-glass surfaces and a good eye clearance of 80 per cent or more, they make an efficient type of eyepiece very free from errors, and there is less curvature of field than the solid Tolles of Fig. 1. However, the field view is small – only 30°. They can be used down to f.5 or even f.4, but are relatively expensive, although the cost of production should obviously be less than the four-element orthoscopic of Fig. 8.

Fig. 5. The achromatic Ramsden is a great improvement on the simple two-element type of Fig. 3. A common design has a plano-convex field lens of crown glass and a cemented doublet eye lens, with a plane or slightly convex surface to the dense flint element

facing the eye. However, many variations are made with the plane surfaces replaced by convex surfaces. The crown component of the eye doublet is usually of barium crown. This achromatic Ramsden is probably the most common three-element type extant and is fitted to many military instruments and to probably 80 per cent of all prismatic binoculars. It has a field from 40° to 50° and an eye clearance of 30–45 per cent. The performance is good and the field flat, and it is usable even down to f.4. The outfield colour of the two-element Ramsden is eliminated by the corrected eye lens, but the dense flint eye surface is vulnerable to scratches. Although made in such large numbers in the focal range 0·6 inch to 1·1 inch, they are not invariably well made or well designed, although those by well-known makers can usually be relied on. The proper description of this type is achromatic Ramsden, but it is often referred to as Kellner type. The eyepiece properly described as of Kellner type is that shown in *Fig. 6*, which has a double convex field lens with a cemented doublet eye lens having a concave surface facing the eye. The type is not common, but had a vogue in microscopy at one time. It has a very wide and flat field (e.g. 60°), but such a small eye clearance that much eye movement is required to see the whole field. A further defect is that dust on the field lens is in focus.

Fig. 7. Dial Sight Orthoscopic, Plossyl, etc. This type was used in large numbers in military instruments, and gives a large eye clearance of 80 per cent combined with a good flat field of 40°. The design is also used for rifle sights where a large eye clearance is a vital requirement. It is also used for erecting purposes in gun sighting and other telescopes. It consists of two fully corrected achromats placed crown sides together and nearly touching. Usually the two cemented achromats are of crossed convex form (both exposed surfaces unequally convex) and are identical, but a number of variations in design exist in which the eye doublet is of shorter focus than the other. By this means fields up to 50° are achieved. Other variations have plane outer surfaces. They are excellent for astronomical use for foci down to 0·6 inch and the only disadvantage is the vulnerability of the relatively soft eye

lens to scratches. The old Browning achromats can be considered as variants of this form, but the separation of the doublets is much greater than for the dial sight type.

Fig. 8. True Orthoscopic. This type, to which the name was originally given, is distinguished by the plano-convex eye lens with the plane side next to the eye, and a triplet field lens. This cemented triplet is overcorrected to balance the errors of the simple eye lens, and consists of a double concave dense flint lens between two hard crowns – symmetrical in some designs, but not in the best ones, in which a field of 50° is achieved; the field is usually 35°–40°. The eye clearance is as large as the dial sight type, viz. 80 per cent of the focus. It has all the other merits of the dial sight type and it is unique in four-element eyepieces in having all the exposed surfaces of hard and durable glass. There are numerous variations in the pattern, but maintaining the characteristic of a plano-convex eye lens. One variation by Goerz, with a plane outer surface to the triplet and a dense barium crown eye lens, achieves a field of 60° at the expense of soft and relatively unstable glass at both ends. A further variant used in some German military instruments has a cemented quadruplet field lens and a field of 75°–80° is attained with long eye relief. Large fields have also been obtained by using an aspheric eye lens with a triplet field lens.

Fig. 9 is a five-element eyepiece used in tank binoculars and giving an extra wide field of 75°. This is selected as one example of the numerous designs of five-element eyepieces that have been used in military instruments. Most of these designs have six air-glass surfaces, and all suffer to some extent in giving ghosts, which detract from astronomical use. The eye clearance of most designs is 40 to 50 per cent and their chief merits from an astronomical point of view arise from their wide fields and their availability at reasonable prices in the form of war surplus lenses. An excellent five-element eyepiece designed specifically for astronomical use was the British Cooke five-lens type consisting of a doublet eye lens and a triplet field lens. It gave 50°–55° field, and was available up to 1940, but not since.

Fig. 10 is typical of the 'Erfle' six-element eyepieces available

today and made for military use. They consist of three separated cemented pairs. The eye lens is undercorrected and the field lens overcorrected. Normally fields of 65°–70° are given, but some rather uncommon ones achieve 80°. The most common of this type in England was made for predictor sights, and has a focal length of 0·75 inch. For astronomical use it is advisable to beware of scratched eye lenses (made of soft glass), also of deteriorated cement in the three doublets. They are also prone to giving one or more ghosts of bright objects. If in good order they are excellent for wide-field spectacular views and their suitability for projection. The eye clearance is about 50 per cent. For planetary observation they are not very suitable.

Zoom eyepieces have become available recently from Japanese sources. They have a large number of separated elements and although coated there is a strong danger in humid climates of scattering of light developing from condensation and filming between the elements, which are not readily accessible for cleaning. For this reason and for the relatively high losses it is doubtful if they are advisable for astronomical use, especially as the power range covered is only 2·5 : 1 and refocusing is desirable after a power change. The alternative of combining a short-focus achromatic Barlow lens with a normal eyepiece of moderately low power can with equal overall length give a power ratio of about 4 : 1 and the fewer elements are all accessible for cleaning. An equally rapid power change to the Zoom, is given by a turret of three or more parfocal eyepieces.

Binocular Eyepieces for Astronomical Duties

The beam-splitter principle as used with high-power binocular microscopes is quite applicable for astronomy, but some loss of light compared with the monocular view is inevitable. This is minimized by using dielectric beam splitters instead of metal films. Matched pairs of eyepieces are, of course, necessary, adding to the cost. However, the view of astronomical objects, particularly the Moon and planets, is enhanced and made comfortable by the use of the two eyes.

Problems of Mars

G. DE VAUCOULEURS

Some twenty years ago I wrote a little book summarizing the then existing knowledge of our neighbour planet. First published in Paris after the war, in 1946, under the title *Le Problème Martien*,[1] it was translated into English by Mr Patrick Moore and appeared in London in 1950 as *The Planet Mars*.[2] When Mr Moore asked me to write this article on 'Problems of Mars' for the *Yearbook of Astronomy* I could not help but reflect on how slowly our understanding of the mysterious planet has progressed during the past twenty years, notwithstanding the tremendous increase in the number of publications on the subject since the end of the war, and especially since the beginning of the 'space age'.

It is true that a number of important details have been added to the picture, mainly through the visual, photographic and polarimetric observations of the French school and the spectrophotometric studies of the American school. But, as we shall see, relatively little basic new information has emerged, and we are still as puzzled as ever by the strange phenomena of Mars. In France, the Pic-du-Midi astronomers, following the lead of the late Bernard Lyot, have taken advantage of the transparency and steadiness of the atmosphere above this high-altitude observatory. Remarkably fine detail showing the resolution of the dark areas into myriads of smaller, ragged spots was observed visually with the 24-inch refractor, especially by A. Dollfus and J. Focas, a visiting astronomer from Athens;[3, 4] but the complexity and patchiness of the dark areas of Mars had been observed before – though never with so much detail – by E. M. Antoniadi with the 32-inch refractor of Meudon Observatory as far back as 1909 and again in 1924 and 1926,[5] an effect which he described as the

'leopard skin' structure. The main new fact brought out by Focas's work is probably that the well-known seasonal variations of the dark areas depend primarily on a 'filling in' of the spaces between the individual minor spots rather than on a uniform darkening, but this adds little light on the nature of these spots. Another interesting observation, due mainly to Dollfus, is that minute changes seem to take place almost daily in the shape and strength of some of the smaller spots, sometimes because of variable cloudiness, sometimes because of intrinsic changes of the surface. However fascinating it may be to follow this surface activity, its nature and mechanism remain completely mysterious.

On a somewhat larger scale the reappearance of some of the famous-infamous 'canals' after long periods of invisibility remains one of the most puzzling and intriguing problems of Mars. It is hardly necessary to repeat once again that the geometric canal network so widely discussed at the turn of the century was, by and large, the product of a persistent optical illusion. It must be emphasized, however, that the dusky streaks observed across the bright reddish desert regions of Mars, whatever their fine structure may be, whether continuous or (more probably) discontinuous, patchy and irregular, are not all due to the optical grouping of randomly distributed minor details of these regions. All experienced observers of Mars agree on this point and this, of course, was already known and well documented twenty years ago. Nevertheless, because the 'canal' controversy had so beclouded the whole problem and discredited the old visual observations, it was gratifying to witness further definite examples of this strange behaviour in our time. To give only two examples we may mention the well-known 'canal' Nepenthes-Thoth connecting Moeris Lacus to the Casius-Utopia area; repeating some of its earlier changes, it was faint and narrow, or possibly double, in 1939 and 1941, but reappeared as a broad dark belt in the 1950s, especially in 1958. It seems as if the variability, in this case at least, is due to the dark matter spreading between the two irregular, patchy branches of the original canal; this variation, which has been repeatedly confirmed by photography, is beyond question.

Another example, perhaps even more puzzling, is the case of the canal Erinnys. This canal had been observed in 1881–82 by Schiaparelli, who named it and recorded it on his map of Mars for the oppositions of 1879 to 1886[6] as a narrow line connecting the east and west tips of Mare Sirenum from Sirenum Sinus to Titanum Sinus. It then vanished from the Martian maps for some sixty years, although it appears on some drawings of G. Fournier in August 1909.[7] It was so completely forgotten that I had no previous knowledge of a canal in this region when in September 1941, observing with the 8-inch refractor of Péridier Observatory at Le Houga, France, I recorded a faint but definite streak extending westward from a new 'oasis' which had appeared just west of the north-east tip of Sirenum Sinus. It extended for some 1,000 miles across Memnonia, crossing the tip of Gorgonum Sinus and ending on the shore line of Mare Sirenum, about half-way between Gorgonum Sinus and Titanum Sinus. Because I could not find any previous record of it and tend to be weary of canaliform appearances I began, over the years, to wonder if the whole thing had not been an illusion, although it looked real at the time. It was, therefore, with much relief that I saw the formation again in exactly the same place in October 1958 through the 24-inch refractor of the Lowell Observatory, near Flagstaff, Arizona.[8] The only difference was that the 'oasis', having continued to develop since 1941, was now very dark and conspicuous, occasionally merging with Sirenum Sinus under poor seeing conditions. Since there is no previous record of the oasis prior to 1941 (except possibly for a very small 'lake' noted by Antoniadi and Fournier in August and September 1924), it is possible that the canal is not a reappearance of the Erinnys of Schiaparelli, but an entirely new, independent formation which happens to follow almost exactly the same path; but is it not more plausible to assume that some pre-existing conditions of the surface of Mars cause the recurrent development of whatever forms canals, even after long intervals of inactivity? On the whole, I tend to share the opinion of G. Fournier, who concluded in 1939, after three decades of patient studies with the 20-inch apochromatic refractor

of the Jarry-Desloges Observatories, that 'the canal phenomenon, by all its properties, is a specifically Martian phenomenon'. This is also substantially the conclusion of A. Dollfus who, even with the advantage of the greater resolving power available at the Pic-du-Midi, had to concede that 'these aspects constitute a very peculiar and specific characteristic of the Martian topography'. Here again we have confirmation of previous findings, but no significant progress in the past twenty years.

It seems to me that the practical limit of resolving power has effectively been reached for Earth-bound observations and that decisive progress, and hopefully the solution of the mystery, will come only through close-up, high-resolution photography and television from interplanetary probes. The Mariner B mission to Mars currently scheduled for launch in late 1964 may resolve the riddle . . . or, perhaps, send back to Earth more tantalizing glimpses of an unearthly activity of which we have no conception.

To prepare for the interpretation of more detailed views of Mars and, later, to select landing areas of special interest, we need a map – or rather maps – of Mars much more precise geometrically than any in existence. If we compare existing maps it is not unusual to find discrepancies of 5 to 10 areocentric degrees between the positions of even well-defined and stable details such as Juventae Fons. Since one degree on Mars corresponds closely to 60 kilometers (as against 111 on Earth), the areographic coordinates of these spots are uncertain by several hundred kilometers. An important contribution to correct this situation was made by H. Camichel, who has measured the coordinates of several hundred spots visible on the best photographs secured between 1941 and 1954 at the Pic-du-Midi Observatory;[9] he is now continuing this program to include the more recent oppositions. One difficulty, however, is that many spots do not look the same on photographs to several observers and the definition of the point to be measured remains somewhat subjective. Furthermore, the identification of photographic features with spots previously observed visually is often uncertain. Finally, the seasonal and secular variations of the Martian topography add to the confusion.

In an effort to remedy and clarify this difficult problem I initiated in 1958 at Harvard Observatory a program for the detailed precision mapping of Mars. This program has proceeded along three main lines. First we collected all the best lists of coordinates of Martian details published between 1909 and 1954, carefully checked the identifications, corrected them when required, and established two 'master lists' of measured points, one for the photographic observations, one for the visual observations; detailed identification maps and tables were published in 1961 in collaboration with R. Wright.[10] As expected, complex systematic errors were disclosed by the intercomparison of these lists which we are at present endeavouring to correct and reduce to a homogeneous system of areographic coordinates. Second, new observations of Mars were secured at Lowell Observatory during the favourable opposition of 1958,[8] from which a list of coordinates was derived and published in 1961.[11] Third, we obtained on loan two fine series of photographs taken in 1954 and 1956 by W. S. Finsen at the Union (now Republic) Observatory, Johannesburg, South Africa, and in 1956 by R. B. Leighton, at Mount Wilson Observatory. Thousands of measurements were made of several hundred points on nearly 800 composite transparencies prepared at Harvard Observatory, where the reduction of this large amount of data is now in progress under the direction of A. Young. The other phases of the Mars Map Project are being continued at the University of Texas. The indication is that by the time of the first mission to Mars we will have a map based on coordinates accurate to one degree or better in favourable cases; this is an improvement of almost an order of magnitude compared with current maps.

The Pic-du-Midi photographs were also used by J. Focas, of Athens Observatory, to measure the brightness of various regions of the surface throughout the Martian year. When the brightness measures are compared as a function of latitude and season, the propagation of the seasonal wave of darkening, alternately from each pole during the Martian spring of the corresponding hemisphere, is strikingly brought out.[12] This extensive investigation fully confirms and adds much detail to this intriguing

phenomenon, first detected over twenty years ago in my visual photometric observations of the opposition of 1939.[13] Here again earlier observations have been confirmed and amplified, but the mechanism of the variations still eludes us.

A major contribution to a deeper analysis of Martian phenomena was made by A. Dollfus,[3, 14] who, since 1946, has continued and greatly refined the polarimetric observations of Lyot. Using the 24-inch refractor of the Pic-du-Midi Observatory, he was able to study in much detail the diurnal and seasonal variations as a function of phase angle of the polarization of light reflected by the surface and atmosphere of Mars. The seasonal variations of polarization of the dark regions reflect also the passage of the darkening wave in the Martian spring which, in agreement with most earlier observers, Dollfus attributes to the influence of humidity spreading from the polar caps and to a re-awakening of vegetal activity on the surface. However, we must admit that the vegetative theory still remains as a plausible, but unproved hypothesis. One difficulty is to understand how a very minute change in atmospheric humidity (water vapour has so far eluded all attempts to detect it) can trigger such conspicuous and large-scale changes.

Dollfus was further able to confirm and strengthen from polarimetric data the value of the surface atmospheric pressure that I derived from visual photometry in 1941,[13, 16] about 80 millibars. E. J. Öpik has recently suggested that, if his interpretation of the Martian atmospheric haze is correct (see below), this value should be increased by perhaps up to 50 per cent because of absorption effects. On the other hand G. P. Kuiper has pointed out that any residual atmospheric haze of small particles, scattering light almost as the molecules of the gas do, should lead to an excessive value for the derived pressure. Here again, we have much new argument, but nothing really new or definitive compared with what we knew already twenty years ago, and some of the criticisms are not valid. The case for strong selective absorption in the Martian atmosphere had been argued as long ago as 1925 by W. H. Wright,[15] who was himself reviving much older

views; and as for the effect of particle scattering, it had been considered and allowed for in my 1941 estimate of atmospheric pressure.[16]

We should perhaps mention here that Russian astronomers have published a truly enormous number of papers about Mars during the past twenty years and especially since the end of the war, but a study of this material is often disappointing. Most of their conclusions parallel those found in the Western literature, or when they differ they can be traced to gross over-interpretation of inadequate data, often because of incorrect photographic photometry of minuscule images taken with small telescopes. While the theoretical work of the Russian school on radiative transfer and atmospheric scattering, following the lead of V. A. Ambarzumian, is fully comparable in quantity and quality to the Western contribution, its application to planetary atmospheres has suffered from the inadequacy of the instrumentation available up to now for planetary studies in the Soviet Union. Certainly this situation will be remedied in the near future when the needs of the Russian space programme begin to require more reliable data.

If we now turn our attention in this rapid and necessarily sketchy survey to the contribution of the American school, it is especially noteworthy for its almost exclusive reliance on photoelectric photometry and especially infrared spectrophotometry and radiometry. Here some distinct progress, bringing to light completely new information, not available twenty years ago, must be noted. G. P. Kuiper, at the McDonald Observatory, opened a new field in the late 1940s and early 1950s when he was first able to record infrared spectra of Mars extending beyond 2 microns.[17] His most important discovery was that of a small amount of carbon dioxide in the Martian atmosphere which, after some re-evaluation of the theoretical background by J. Grandjean and R. M. Goody,[18] is now estimated at about 40 meters under standard conditions (1 atm., 0°C); percentage-wise this makes up a small fraction, about 2 per cent, of the atmospheric gas, which is still believed to be mainly nitrogen with perhaps a small amount of argon of radioactive origin. Kuiper obtained also evidence that

the reflection spectrum of the polar caps (more precisely the surface deposit) shows the characteristic drop of reflectivity of ice beyond 1·5 micron, thus establishing beyond doubt the long-held view that the polar caps of Mars are merely thin deposits of ordinary water ice. This was further confirmed a little later by Dollfus from laboratory experiments on the polarization of light reflected by sublimating deposits of ice crystals formed under reduced pressure and at a very low temperature.[14] Conflicting identifications were proposed, however, by Kuiper and Dollfus for the reddish dust that covers the bright areas of Mars. By matching the infrared reflection spectrum of Mars with many terrestial samples selected in the deserts of the South-western United States, Kuiper[17] suggested that the bright regions of Mars are composed of igneous rocks similar to felsite, which mineralogists tell us is a common rock formed of orthoclase (aluminium and potassium silicate) with quartz grains in occlusion. On the other hand, Dollfus,[14] after very extensive testing of natural and artificial materials, found that the polarization curve of the bright regions of Mars (corrected for atmospheric effects) matches precisely that of limonite, a sedimentary deposit of hydrated iron oxide (Fe_2O_3, $3H_2O$). It is unfortunate that up until now no cross-checking of each proposed identification, i.e. of felsite by polarization, of limonite by infrared spectrophotometry, has been carried out.

More precise information on the reflection spectrum of Mars than was available twenty years ago was obtained through the work of R.v.d.R. Woolley and his collaborators at Mount Stromlo Observatory, Australia,[13, 19] of H. L. Johnson and this writer at Lowell Observatory,[19] and most recently of P. Guérin at the Haute Provence Observatory.[20] Woolley measured the spectral reflectivity of Mars in the visible spectrum by narrow band photographic photometry during the oppositions of 1952 and 1954; Johnson made some photoelectric measurements in the yellow, blue and near ultra-violet in 1954, and I supplemented these measures in 1958 by making further photoelectric observations through broad-band filters from 3,200 Angströms to 6,900

Angströms;[19] these observations disclosed the fact that while Mars is red in the visible spectrum (i.e. its albedo increases with wavelength), it is essentially 'grey' in the ultra-violet and very dark indeed (i.e. the albedo is very low, about 0·05) and essentially constant between 3,000 A. and 4,000 A. This unexpected finding pretty much disposed of the theory in favour during the past two decades, according to which the obscuration of the surface of Mars in blue, violet and ultraviolet light is due to a haze of microscopic ice crystals floating in the upper atmosphere. Ice crystals should reflect more in the ultraviolet where Mars is almost as black as soot. The hypothesis that the Martian atmospheric haze is made up of carbon particles, first advanced in 1953 by B. Rosen of the Astrophysics Institute at Liège, was therefore recently revived by E. J. Öpik in a new analysis of the Martian atmosphere involving strong true absorption;[21, 22] but the formation of carbon particles of the required size in the atmosphere is hard to explain, to say the least. The nature of the obscuring haze of Mars, and the mechanism of its occasional clearings, repeatedly observed to take place near opposition and more frequently than chance or selection effects would permit, remain among the most irritating puzzles of the Martian problem. Very little progress has been made in this respect during the past two decades.

A detailed study of the spectrum of the bright desert areas of Mars by photographic spectrophotometry was made by P. Guérin of the Astrophysics Institute in Paris, at the time of the opposition in 1960.[20] His spectral curve extending from 3,100 A. to 6,200 A. confirms the previous photoelectric results, but adds much fine detail, in particular some diffuse bands, as yet unidentified, in the near ultra-violet; they give us at least a new hope of identifying the nature of the haze particles.

The most striking and far-reaching discovery of the past twenty years in the whole field of Martian studies must, however, be credited to the American astronomer W. Sinton of Lowell Observatory. In 1956, while at Harvard Observatory, he detected in the infrared spectrum of Mars near 3·5 microns a weak double band, not present in the lunar spectrum serving as comparison,

and which he also observed in the reflection spectrum of plants, such as the leaves of lily of the valley.[23] With more sensitive receivers, using a Golay cell and higher spectral resolution, he repeated and fully confirmed this observation in 1958 and again in 1960 with the 200-inch reflector on Mount Palomar; Sinton was even able to show that the two absorption bands, to which a weaker third band was then added, are present only in the spectrum of the dark regions of Mars and do not appear in the spectrum of the bright desert regions.[24] This was convincing proof that the responsible substance is not an atmospheric gas, but is located on the surface of the dark areas. The three bands centered near 3·45, 3·58 and 3·69 microns, are characteristic of heavy organic molecules; the first is probably due to the CH_2 bond in aliphatic compounds, the other two may be bands of acetaldehyde, according to N. B. Colthup,[25] but final identification will require further work. At any rate, taken in conjunction with all the previous photometric and polarimetric evidence, these observations come probably as close as we can hope to get to final proof of the presence of life on Mars, short of direct exploration of the mysterious neighbour planet. The next twenty years may well give us the final answer to this question, the most fascinating of all the problems of Mars.

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Astronomy and Space Research

J. G. PORTER

Although the first artificial satellite was launched only five years ago, the results of space research have already reached alarming proportions, and it is difficult to keep track of recent developments. In the popular Press, the launching of man into space is by far the most spectacular aspect of this subject, but from the scientific point of view the results obtained by instrumented probes are of far greater importance. In this field the Americans are supreme, for they have a unique gift for 'packaging' their instruments in a remarkably small volume.

Science is the art of measurement, and it is in the collection of new values of astronomical quantities that space research is making its greatest impact on science. There are many obvious questions that we should like answered, and the Russian Sputnik which photographed the other side of the Moon gave an illustration of what can be done in this connexion. Similar results for the major planets will certainly follow; indeed, by the time these words appear in print the Mariner probe will have made its journey towards Venus, and a similar spacecraft will attempt the journey to Mars in 1964. There are many questions about these planets that we should like to ask – whether Venus is really covered with water or not, and if not, what are the clouds made of? Is there really some form of aurora that illuminates the dark side of the planet, and if so, what is the strength of the magnetic field that controls it? And on the way to Mars, the old question of life on Mars may be answered, but the more important scientific questions relate to the nature of its surface and its atmosphere, the strength of its magnetic and gravitational fields, the types of clouds and storms that occur there.

These are observations that are best made by instruments, and do not require the presence of a human being. They involve long journeys, but there will be much to do on the way, in collecting information about interplanetary space, which is by no means as empty as we had once supposed. The Ranger probes have been designed to investigate, among other things, the nature of the particles in space, the interplanetary magnetic field and the study of solar radiation. And all of these long-range probes will be able to look back at the Earth and record measurements of its albedo, its size and its colouring. Perhaps in time we may venture to send our instruments to Mercury or to have a closer view of the Sun, to study under ideal conditions that wonderful corona, or the sunspots and the great prominences.

There is so much to learn, even about our own Earth. The close artificial satellites (how many readers of this article could quote offhand the number of earth satellites that have been launched, and the number still in orbit?), even those which carried no instruments, have already told us a great deal about the Earth and its immediate surroundings. Their behaviour in orbit has shown us that the atmosphere is denser than we had thought, and has given us measurements of the irregularities in the gravitational field which have led to a better knowledge of the internal structure of the Earth and of its overall shape. With the more recent rockets and satellites we have found the Van Allen belts of radiation, but what lies beyond them? What is the real origin of the zodiacal light and of the gegenschein? Again, there is much to do in making maps of the Earth's surface. Although we have accurate maps of whole continents, these are isolated portions of the surface, and are not well fitted together.

These errors in the distances between continents are something of an embarrassment to the space scientist, who must have exact positions of his tracking stations if he is to deal accurately with the orbit of a space probe. Clearly something better than the present astronomical methods for determining latitude and longitude are needed, and this will come when a really permanent satellite is placed in orbit. If its position at any given time can be

predicted with great accuracy, then observations of this satellite will give very accurate positions of the observer on the surface of the Earth. Conversely, of course, such a satellite will also afford a very accurate measure of time for a station at a known position.

Observations of any kind, whether of artificial satellites or of planets, of Sun, Moon or stars, will always suffer from disturbances due to our unstable atmosphere, and for this reason there are already several programs under discussion for launching a telescope into an orbit about the Earth. Even in the present state of our knowledge, it would be possible to maintain such an instrument in an orbit which remains for ever in sunlight, and this would make it invaluable for a prolonged study of the Sun. Similarly a telescope could be used to extend our knowledge of the Galaxy and of the distant nebulae, since it would be possible to obtain spectra at wavelengths which are not accessible to us on Earth, because of the atmospheric absorption. But telescopes of this kind are not the last word in instrument design, and there is much talk of having a larger telescope on the Moon, where it could be built on a more stable foundation and would still be free from atmospheric disturbance.

If the reader imagines that all these plans are vague hopes for the future, a sort of science-fiction effort, then he is greatly mistaken. Space research today has passed far beyond the vague general plans (perhaps enlivened by a few differential equations) that one reads in the more popular journals. The professional space scientists have already worked out all the best orbits, with the time of launching, the amount of thrust required, and the details of the measurements they wish to make, and in many cases they have already booked a date for the use of the launching pads. The progress that has been made in so short a time is quite astonishing. For the first three months of 1962 I was privileged to work at the Jet Propulsion Laboratory of the California Institute of Technology at Pasadena, Calif., U.S.A., which is, I believe, the only private research centre in that country involved in the design and construction of space-craft. Here in Pasadena the probes are built and tested, the tracking stations follow them in flight, and

the computing laboratory performs all the necessary calculations: they do everything, in fact, except the actual launching of the vehicles into space.

I was most impressed by all that I learned at this enormous place, and most of all by the progress that had already been made, and by the thoroughness with which every phase of the flight of a space craft was studied. Nothing was too small to be studied in minute detail, whether it concerned mathematical theory, physics, chemistry, engineering, electronics, or any other branch of science which might be called upon. The tracking stations associated with this work are at Goldstone (about 150 miles from Pasadena), at Woomera, Australia, and near Johannesburg in South Africa. These are linked directly with the computing laboratory in Pasadena. In solving their equations to find the errors in the orbit or a probe, so as to deduce suitable corrections, many other quantities may also be found, for the high-speed computers that are used think nothing of solving a few hundred equations with sixteen unknown quantities! Thus, even if the probe fails in its main objective, it is still possible to obtain a good deal of useful information about astronomical measurements, quite apart from that collected by any special instruments which are being carried.

None of this research would be possible without the use of the high-speed electronic computers, which have already passed beyond limits which were considered quite impracticable (because tremendous speeds mean greater complications) a few years ago. The modern machines have been greatly simplified for everyday use, and there are already a number of commercial machines which perform their calculations in a matter of microseconds. The vast amount of computational research that has already gone into the various space projects has been made possible by such machines as this, and they are, of course, absolutely essential in computing the orbits in which the probes travel. All observations, whether made by radar, radio, or optically, are communicated directly to the computing centre, which reduces this very diverse material to a uniform system from which the orbit, and the corrections required to change it to the required trajectory, are com-

puted in a few minutes. Probes and rockets travel so quickly that no time must be lost, for it is the first hour or two of flight that are vital; the earlier a correction is made the less fuel has to be used, for each delay means a more extravagant manoeuvre farther out in space.

The present series of experiments at J.P.L. is concerned with the use of instrumented vehicles (they are not interested in 'man in space') such as the Ranger probe to the Moon and the Mariner, which is intended for planetary research. There is so much that we should like to know about the Moon and its past history that is quite a fascinating thought that all our questions may be answered by one single landing on the surface, giving us a measurement of the magnetic field, or the density of the surface rock, made by instruments suitably protected against a crash landing from a Ranger probe. Later there may come a 'soft' landing from the same type of space-craft, and although the Rangers so far launched have had some very bad luck, we may be confident of success in the future – these people learn fast! The Mariner is a more advanced type of vehicle intended for planetary exploration, but such trips will necessitate the ability to control the probe over vast distances, and for the present plans are confined to the distance of the planet Mars. Yet this volume of space – say out to two astronomical units from the Sun – contains enough material for the most enthusiastic scientist. So there are plans already afoot for the study, not only of the planets, but also of their satellites, of the comets and meteors and the magnetic field of space, of cosmic rays and other charged and uncharged particles.

Radio control of a probe at such distances is feasible, but there seems to be a growing conviction that optical tracking is of enormous value, and that the two methods, used in partnership, would greatly assist in the control of future interplanetary probes. It is not difficult to show that a probe fitted with a highly reflective surface (as is the case with the Echo satellite) would be visible in a large telescope over distances reaching far beyond the Moon, and this would at least make the initial corrections easier to calculate and to monitor.

The plans that are being made are based on the present state of our knowledge, but the real thrill in research is the discovery of the unexpected, and we may be sure that the future holds a great deal that we cannot at present foresee. The discovery of the Van Allen radiation belts that encircle the Earth have already provided one example, while the success of the Tiros weather satellite promises a much better understanding of atmospheric circulation. There is one effect of space research which will most certainly be evident in the next decade, and that is the impact of all this new technique and its results on the science of astronomy. Like everything else, astronomy has its fashions, and for nearly half a century very little notice has been taken of the solar system, all the efforts of most of the world's astronomers having been directed to the study of astrophysics. But now the solar system has assumed a new importance, space scientists want to know more and more about the Sun, Moon and planets, and the astronomers are not in a position to supply the information. Their telescopes are fully occupied with the stars, and those interested in space research cannot 'buy time' on the big telescopes. But these people 'think big' – and there is plenty of money available – so before many years are past, we shall see new telescopes being constructed in many parts of the world solely for the purpose of studying the solar system, and of following the space probes in their long journeys. To my mind, this means inevitably that astronomy will be split into two distinct fields – on the one hand a tremendous resurgence of interest in the Sun and its family of planets and satellites, and on the other, the continued study of the distant stars.

Now, it is already clear that while many scientists have welcomed the new line of research, there are others who fail to recognize its importance. Yet let us make no mistake – space research (if not space travel) is here to stay. It has already made a profound effect on many branches of science, but even more valuable has been the increasing demand for more trained scientists with fresh ideas. There is nothing in this new branch of research that relies on tradition or experience – it is a young man's

world, a vast field for the enterprising. So there is a demand for better training, and the growth of astronomy schools, particularly in the United States, has been very remarkable. Whereas only three or four years ago it would have been difficult to find more than one or two universities that offered courses in celestial mechanics, there are now a larger number, some of which maintain advanced courses to very large classes. This is not yet true in England, where the space effort is hardly comparable with that in the U.S.A. Our entire space budget of about half a million pounds a year can hardly compare with any one of the many projects that are being discussed by the Space Administration in America. The most spectacular of these, Project Apollo, plans to land three men on the Moon, possibly in 1968, and it is already costing over 1,000 million pounds a year.

In everything they do in this subject the Americans show a wide appreciation of the possibilities that is most stimulating. Early in 1962 one of their largest rockets was sent up with a payload of about 90 tons of water, which was released in the upper atmosphere just to see what would happen. The results in some respects were quite different from the theoretical conclusions reached by physicists on the basis of laboratory experiments, and the results are, in consequence extremely valuable. But is that not true of all of this space research? No longer confined to his bench, man can send his instruments out into unlimited space, there to conduct experiments that would be impossible on Earth.

Observing the Sun

W. M. BAXTER

Many amateur astronomers who study the night sky have never observed the Sun, or if they have done so it has only been in a perfunctory manner, and yet it is our nearest star and as such commands our special attention. In the Sun we have a close-up view of a star which is only 93 million miles away from us. This may seem a great distance, but not when compared with that of the stars of the night sky. Light from the next nearest star takes over four years to reach us, travelling at the enormous speed of 186,000 miles a second, but from our nearest star – the Sun – it takes only 8½ minutes. Moreover, the Sun is available for study on every clear day all the year round, which is more than can be said for the other stars, the Moon and the planets.

Some celestial objects are very faint and require large telescopes for making a detailed study, but in the Sun we have plenty of light, even an excess of light, so that interesting observations can be made with quite small telescopes. This excess of light, and of heat, can be a danger, and precautions must be taken to ensure that the light and heat concentrated by the telescope do not directly enter the eye or irreparable damage will be done.

For amateurs with the usual small refracting telescopes, with object glasses of 2 or 3 inches diameter, undoubtedly the best way to observe is to project an image of the Sun's disk through an eyepiece of suitable power on to a white card. It is true that telescope eyepieces are sometimes supplied with dark glass caps by the makers, supposedly for observing the Sun, but it is too risky to look directly through a telescope fitted with one of these caps, as the object-glass forms a small primary image which is magnified by the eyepiece, and from the latter emerges a tiny

beam of light in which the whole of the Sun's light and heat, collected by the larger object-glass, is concentrated. This is liable to crack any filter cap on the eyepiece.

Some observers will have what is known as a solar diagonal, which directs the light at right-angles to the telescope, being reflected from the front surface of a wedge-shaped piece of plain glass. This gives diminished light at the outlet where the eyepiece is inserted, and allows the heat to go straight through out of harm's way. Even so, a dark filter on the eyepiece is necessary, as even the diminished reflected light of the Sun is still too bright for viewing. Projecting the Sun's magnified image on to an otherwise shaded card is to be preferred, as more of the fine details can usually be seen in this way.

First let us run briefly over some facts about the Sun. It is an average star 864,000 miles in diameter and, as has been said, 93 million miles from us. We circle round it once a year and as the Earth's axis is tilted (by $23\frac{1}{2}$ degrees) to the plane of its path round the Sun the latter appears at different heights, at midday, at different times of the year – high in summer and low in winter. The Sun's axis is also tilted to the Earth's path (by $7\frac{1}{4}$ degrees), and the combination of these tilts results in the north end of the Sun's axis appearing to us sometimes inclined to the left and sometimes to the right by $26\frac{1}{2}$ degrees; sometimes away from us and sometimes towards us by $7\frac{1}{4}$ degrees.

The Sun is like an extremely hot ball of gas, having a surface temperature of about 6,000° C. The gases near the surface are extremely rarefied, but they rapidly increase in density towards the centre, so that we do not see very far below the surface. When we look towards the centre of the Sun's disk we see deeper into the gases than we do towards its edge, or limb; that is, we see farther into the hot, and therefore brighter, interior than we do on the limb. This gives the effect known as limb darkening, which is noticeable when we see the Sun's projected image.

We shall probably see some sunspots, too. These can be likened to solar storms, which are the surface manifestations of much larger disturbances in the interior. The spots normally have a

dark centre, or umbra, with an outer lighter border, the penumbra, but the centre is dark only by comparison with the extremely brilliant surface of the Sun, as the 'dark' spots have a temperature of 4,000° C. – only 2,000 degrees cooler than the surface temperature.

Sunspots do not appear regularly, but follow a pattern both in abundance and position. They follow a strange, and not fully understood, cycle of about eleven years. At sunspot 'minimum' the face of the Sun may be entirely free of spots for days on end and then, as time passes, small spots will begin to appear in the northern and southern latitudes on the Sun – at about 40 degrees N. and S. at the most. The spots will become more prolific as the years go by, gradually approaching nearer the equator from both directions until, four or five years after 'minimum', we reach sunspot 'maximum', when observers can be sure of seeing a much-spotted Sun at any time. Occasionally the spots, which individually come and go, are large enough to be seen with the naked eye (through a dark filter) and they must then be at least three times the size of the Earth. Some of the smaller spots only last a matter of hours, but the larger complex spot groups can last for months, and can be followed as they are brought into view repeatedly by the Sun's rotation.

Most of the sunspots now appear in two bands at about 15 degrees latitude both N. and S., but after 'maximum' the numbers begin to diminish, although their appearances still continue in the direction towards the equator. As they are disappearing at the equator at the minimum (some six or seven years from maximum), the spots of a new cycle begin to appear again in the high latitudes; there is, in fact, an overlap with new cycle spots appearing in the high latitudes as the old cycle spots are disappearing in the low latitudes. Spots are not often seen on the equator and rarely in latitudes higher than 40 degrees – never, one might say, higher than 45 degrees N. and S.

Mention has been made of the Sun's rotation. This has a period of about 25 days, but as the Earth is going round the Sun in the same direction as the Sun is rotating, it takes another 2 days for

any point on the Sun to 'catch us up'. So to us on the Earth the Sun appears to rotate once in about 27 days. We say 'about', as the Sun does not rotate all at the same rate as a solid body would do. The equator rotates faster than parts near the poles. At about 40 degrees latitude the rotation period is about 27½ days, while still nearer the poles, at latitudes of 80 degrees, the period is about 30 days. The mean periods adopted are 25·38 days for the Sun itself, corresponding to latitudes of about 20 degrees, or 27·27 days as seen from the Earth. The speed of rotation is not rapid and no flattening at the poles has been detected.

The different rotation periods can be noted if two spots, one in a low latitude and one in a high, are seen in about the same longitude and can be followed for more than one rotation. When they come into view the second time the low-latitude spot will be in advance of the other, and this advance will be extended if the pair are seen during a later rotation.

All this is to show that the observer with quite modest equipment will have much of interest to see in the comings and goings of sunspots. He can plot their positions, as will be described later, and can draw the shape of particularly interesting spots, while the changes in the active ones can be noted during the time in which they pass across the disk to disappear at the west limb. Some may appear again at the east limb some two weeks later with considerable changes in both shape and size. A rough estimate of size can be made from the solar disk diameter (864,000 miles) and it will be found that really large spots can be of very impressive size. One large stream of spots, in 1947, was measured as covering an area of 7,000 million square miles – about 100 Earths could be fitted into this area.

The projected image will also show bright patches of hot hydrogen just above the surface of the Sun, known as faculae. These are not generally visible near the brilliant centre of the disk, but they are plainly seen near the limb, where they show up against the limb darkening. They are irregular patches and can be very extensive; sunspots frequently have their beginnings in the midst of faculae.

Another feature that can be seen, if a sufficiently high-power eyepiece is used for projecting and if the air is very steady, is the surface granulation. Bright specks cover the surface, and these are in constant movement, indicating that the surface of the Sun is in a turmoil. They may appear minute, but each, in fact, is something like 900 miles in diameter.

This is not the place to consider observing the Sun with special equipment, but possessors of solar spectroscopes will know what can be seen with this instrument in the monochromatic light of hydrogen – the chromosphere and prominences. As this brief account is for the ordinary amateur with just a small telescope, we will proceed with the method to be adopted for seeing the limb darkening, the surface granulation, the sunspots and faculae, for here is an abundance of interesting material. Unfortunately we are at present near sunspot minimum, the last maximum having occurred at the end of 1957. However, individual interesting spots are still appearing fairly frequently and a more active time will soon be approaching.

Discarding other methods, we will concentrate on the best way to project the Sun. It is a satisfying view that can be seen at the same time by more than one observer, it shows considerable detail on the disk, and there is no possible danger from the concentrated heat.

Fig. 1(a) shows an arrangement for projection with a small refracting telescope. The cardboard square over the object-glass is to provide the necessary shade from direct sunlight, the dotted square near the eyepiece indicating an alternative position. The rod supporting the projection card frame should be fixed to a split bracket which can be clamped just loose enough to rotate round the telescope tube for orientating the Sun's image; if such a clamp is felt-lined it will rotate smoothly. Alternatively it can be clamped tight on the draw-tube, which itself rotates. Its distance from the telescope axis should be such that this axis, continued, would pass through the centre of the projection card. For small telescopes with object-glasses of, say, 2 or 3 inches a convenient disk size is 4 inches, but a 6-inch disk is possible with some diminution of

light. The length of the rod is best decided by trial and error with various eyepieces, but in any case some small adjustment should be possible – either at the telescope bracket or at the projection frame – as the Sun *appears* to be slightly larger in diameter in our northern-hemisphere winter than it does in our summer. The Earth's path is slightly elliptical, and we are nearest the Sun in our northern winter – or in the southern summer.

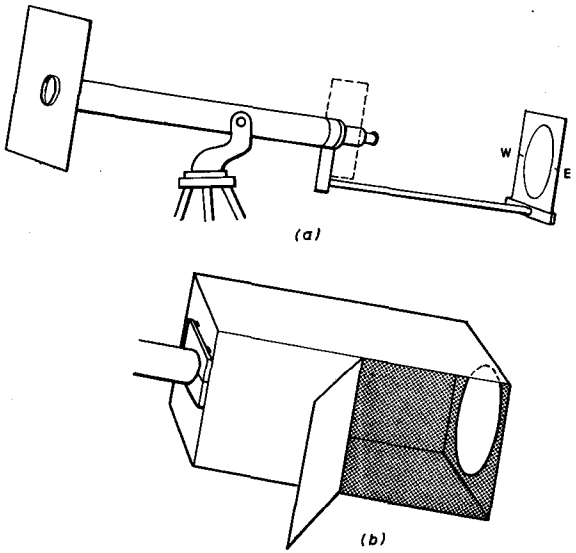

Fig. 1.
(*a*) *Projecting the Sun* (*b*) *Projection Box*

The card itself should be smooth and white, but not so smooth that it gives a reflection from its surface. Cartridge paper is good, but better still is matt bromide paper unexposed and just fixed in hypo. It should have a circle of the required diameter inscribed on it with an east-west horizontal diameter marked – east to the right and west to the left.

The procedure is to focus the Sun's image on the card with the eyepiece chosen to give the required disk diameter as drawn on the card. The distance of the card from the telescope must be adjusted so that the focused image exactly fits the drawn circle. The card must then be orientated by allowing a sunspot to drift across the card (carried by the Earth's rotation) and turning the rod round the telescope tube until the spot exactly follows the east–west line. With the ordinary altazimuth stand illustrated, it is necessary to correct the orientation every five minutes or so, for accuracy, but if the observer is the fortunate possessor of an equatorial mount, then, once set, the orientation remains correct.

The orientation of the projected Sun is reversed mirror-wise compared with the naked-eye view; and while the north is still at the top with south at the bottom, the east limb of the Sun is at the right of the card and the west at the left. Assuming no clock drive (which would require an equatorial stand anyway), the image will be drifting from right to left all the time, and must be continuously brought back as each sunspot is recorded.

For recording, the projection card should have an additional fine network of pencil lines, say $\frac{1}{2}$-inch squares and diagonals within the circle. A similar stout card, that can be handled, should have a similar but heavily inked grid within a circle of the same size. This has clipped on it a sheet of thin paper on which a similar plain circle has been drawn and through which the inked grid can be seen. Then with these circles, and the east-west lines coinciding, we have a reference which enables the exact position of spots to be recorded on the thin paper 'blank'. Thus a record can be made from day to day of the spots that come and go and the changes that take place in the longer-lived and more complicated groups – a fascinating study. The date and time with seeing conditions should, of course, be noted down.

Fig. 1(b) shows an even better arrangement, as the image is projected into a dark box, thus enabling much finer detail to be discerned. The box itself can be of strong cardboard or thin wood with half of one side cut away as shown, but the end fixed to the telescope draw-tube should be stout enough to support the weight

of the box without sagging. The front end can be of thick wood or be reinforced with a sheet metal square with some clamping arrangement. It should be able to slide on the draw-tube, slightly, to allow for adjusting the solar diameter for the summer-winter difference referred to above. If just a pleasing view is wanted, then the size of the solar disk is unimportant, but if serious recording is to be undertaken the length of the box will have to be carefully chosen to suit the particular size of disk. In the darkened box, the inside of which should be painted dead black if possible, a 6-inch disk is convenient.

The back of the box contains a projection card, the details being the same as outlined above, and the procedure for orientating and recording sunspot positions is, of course, the same also.

Depending on the weight of the projection arrangements it may be necessary to fix a small removable counterweight to the front end of the telescope so that the instrument is balanced without difficulty. In Fig. 1(a) the cardboard square, if at the object-glass end, helps the balance.

The owner of a reflecting telescope will readily see that the same arrangements can be adapted to his equipment; but if the main mirror is a large one it should be stopped down to about 4 inches diameter, or there may be trouble from the excessive heat.

Constructional details and dimensions have purposely been omitted, as experience shows that, once the principle is clear, the amateur will soon make a suitable contrivance to fit the materials he has to hand.

If any amateur astronomer who has not seriously observed the Sun decides to take up its study, he will find it very fascinating, as the face of the Sun is never the same, and it is hoped he will join the Solar Observing Section of the British Astronomical Association, where he can contribute to the co-operative efforts of that active band of workers.

Variable Stars

ROGER GRIFFIN

The first recorded discovery of a variable star (other than a nova or temporary star) was made in 1596, when Fabricius observed in the constellation Cetus a star where none had been seen before. During the following century the star was found to vary rather regularly in brightness over a large range, and was christened *Mira*, meaning 'the wonderful'. It normally varies from about the third to the ninth magnitude with a 'period' (time interval between successive maxima) of 330 days. Probably, however, the variations of *Algol*, in Perseus, were already known to the Arabians in the Middle Ages, for the name they gave it means 'the demon'. Normally of the second magnitude, *Algol* falls rapidly to between third and fourth magnitude every sixty-nine hours, regaining its usual lustre within a few hours of the minimum; its changes can easily be followed with the naked eye. In 1963, minima will occur in the evening (between dusk and 11 p.m.) as seen from Great Britain on the following dates:

Jan. 7, 10, 27, 30; Feb. 19; Mar. 11, 14;
April 3, 26; May 16; June 28;
Aug. 10; Sept. 2, 22; Oct. 15;
Nov. 4, 7, 27, 30; Dec. 17 and 20.

Several other stars are now known whose light variations are obvious to the unaided eye. In addition, there are some naked-eye stars (the Pole Star, for example) which undergo changes of brightness too small to be observed visually, but readily detected by photoelectric equipment. Many thousands of telescopic stars are known to be variable, and their study has long formed a considerable and fascinating branch of astronomy. The remarkably

diverse characters of the light changes of different stars reflect equally great diversities of the stars themselves; in many cases it is possible only to guess at the causes of the variations.

Many stars which show light variations are not in themselves variable; their changes result from the eclipses of one star by another. Very many stars which appear single in even the largest telescopes are in reality double, twin suns revolving around one another in an orbit under the influence of their mutual gravitational attraction. If we happen to see the orbit practically edge-on, the stars eclipse one another at every revolution; the eclipses may be partial, total or annular. Often the two stars eclipse one another alternately, but in certain cases only one of them can ever be eclipsed. Periods are known from under five hours to over twenty-seven years, while variations in brightness of up to four and a half magnitudes occur.

These 'eclipsing binaries' provide us with much information about the member stars, information which is otherwise very difficult to obtain. For example, it is possible in favourable instances to discover the masses of the stars, their sizes, and the amount of their distortion from the spherical shape (owing to their rotation and each other's gravitational attraction). Such studies demand spectroscopic measurements of the motions of the two stars, as well as an accurate determination of the 'light curve', in which the brightness of the system is plotted graphically against time.

The simplest form of light curve shows a constant brightness during most of the period, and a more or less sudden dip and recovery where (usually) the brighter of the two stars is being eclipsed. A V-shaped dip demonstrates that the eclipse is partial, whereas a period of constancy at minimum light betrays a total, or less commonly annular, eclipse. Between successive 'primary minima' a smaller dip, caused by the eclipse of the fainter star by the brighter, is often observed. If the secondary minimum is exactly half-way between successive primary minima, the orbits of the twin stars are probably circular; if not, they must be elliptical. The light curve is frequently not horizontal even between

eclipses. Sometimes the fainter star reflects a certain amount of the light of the brighter, causing the light curve to slope upwards towards the secondary minimum – for we see most of that part of the faint star which is illuminated by its companion around the time of secondary minimum. Photoelectric measurements show such an effect in *Algol*. Very often the component stars of an eclipsing binary are so close to one another that they are not spherical bodies but distorted into ellipsoids. As they revolve, the surface area presented to our view changes continuously and so therefore does the brightness. Such systems are called 'Beta Lyrae stars' after the first discovered example. Many binaries, particularly those of short period (less than a day) whose light curves show this evidence of severe distortion of the stars, have primary and secondary minima of equal depth; they are known as 'W Ursae Majoris stars'.

Turning now to stars which are intrinsically variable, we are confronted by objects of many different kinds, from those which vary with the utmost regularity to some whose changes seem to be completely capricious, and from ranges of variation of mere hundredths of a magnitude up to eight or nine magnitudes, and, in the cases of some of the more catastrophic types of variability, even more.

The most strictly periodic of the intrinsic variables are the Cepheids (named after Delta Cephei) and their cousins the RR Lyrae stars. These stars vary in brightness by pulsating – they expand and shrink again rhythmically. The range of variation is rarely much more than one magnitude, and the period of oscillation rarely more than a few weeks. Nearly all the Cepheids which were known fifty years ago had periods between three and thirty days. Similar variable stars were found in the Magellanic clouds, our nearest neighbour galaxies, and it was noticed that the brighter the star the longer was its period; this is the famous 'period-luminosity relationship'. This was an important observation, since it suggested that wherever one saw a Cepheid one could infer its absolute brightness or candlepower simply by determining its period, and with this information one could readily calculate its

distance. Cepheids are all stars of exceptionally great absolute brightness and can therefore be seen from enormous distances, which are extremely difficult to measure; and the prospect of measuring them by timing variable stars seemed most attractive. Unfortunately it has turned out that Cepheids cannot be trusted everywhere to conform to the same period-luminosity relationship, and although they furnish a useful guide to distances, the accuracy is less than was once hoped.

Some of the earliest systematic studies of globular clusters revealed large numbers of variable stars which, while otherwise like Cepheids, had periods mostly less than a day and occasionally as short as two hours. They became known first as cluster-Cepheids, and later as RR Lyrae stars after a bright specimen discovered outside a cluster. The study of these variable stars has become quite a subject in itself, since it has appeared that their pulsations represent a particular and well-defined stage of stellar evolution. The absolute average brightness of the RR Lyrae stars in any one cluster is the same, regardless of the period of variation; but whether it is the same for all clusters is still an open question.

A somewhat less well-defined class of variable star than the Cepheids is that of the 'long-period variables,' of which *Mira* Ceti is an example. Most stars of this type have periods of variation of 200–400 days, although a few are known with periods as short as 100 and as great as 600 days. Ranges of five and six magnitudes are common, and Chi Cygni, which at maximum is clearly visible to the naked eye, drops at minimum to between the thirteenth and fourteenth magnitudes – a range of over eight magnitudes. Unlike the Cepheids, long-period variables do not show strictly regular fluctuations of brightness; although a mean period can be assigned to any star, the interval between two successive maxima may not be of exactly this length, deviations of two or three weeks being common. Neither does the light curve repeat itself exactly at every cycle; deviations of a whole magnitude from the average maximum brightness are frequently observed, and the light curve may show secondary humps or waves in some

cycles but not in others. *Mira* itself shows notable differences between one maximum and another: normally near third magnitude, it occasionally exceeds the second, becoming one of the brightest stars in its part of the sky; while at other times it scarcely reaches the fifth magnitude.

All the long-period variables are red stars, some of them strikingly so. Most, if not all, of the reddest stars are of unstable luminosity, although not all fall within the class of long-period variables: many are assigned to the 'semi-regular' and 'irregular' groups, characterized by increasingly haphazard types of fluctuation. Although it is difficult, if not impossible, to draw hard and fast lines between the three types, the semi-regular and irregular variables generally show a smaller range of variation than the long-period stars, one or two magnitudes being typical. In the case of the semi-regular variables, it often appears that a period in the neighbourhood of 50–100 days can be traced for several cycles; but after a time the light curve changes its character and the period is lost. Several semi-regular stars belong to a subgroup named after RV Tauri, and tend to show two periodicities, the longer one being something like 1,000 days. RV Tauri itself usually shows a cycle of about eighty days, which includes two maxima of unequal depths, superimposed upon which is the long period; and at the minimum of this slow oscillation the eighty-day cycle becomes nearly or quite untraceable.

In the types of variation so far described, the changes of brightness of the stars concerned are reasonably smooth and continuous. There are, however, several other classes of stellar variability which are characterized by long quiescent periods suddenly interrupted by great, and in some instances catastrophic, changes in brightness. In all except one of these classes the sudden changes are outbursts; but there is one group which shows sudden diminutions of light. This group is named after R Coronae Borealis, whose variations are very typical of the class as a whole. R Coronae is usually just brighter than the sixth magnitude, clearly if faintly visible to the unaided eye near the centre of the arc of bright stars which delineate the constellation of the Northern

Crown. It may maintain this brightness for years at a time, the record period being nearly nine years in 1925–34. Then, quite unpredictably, a decline sets in and within a few weeks the star has been known to fall as far as the fourteenth magnitude. The decline is not always so profound; sometimes, indeed, it is arrested even before the seventh magnitude is reached. The cause of the variation is still in doubt, but seems to be due to some sort of veiling of the atmosphere of the star rather than to a pulsation or change in temperature. The spectroscope reveals an excess of carbon in the atmospheres of the R Coronae variables.

A family of stars which show abrupt increases of light is named after U Geminorum. Such variables spend most of their time at a constant, or nearly constant, minimum brightness, and then at fairly regular intervals of a fortnight upwards they brighten by two to four or even five magnitudes, the increase taking place in little more than a day. Sometimes the decline to minimum, which commonly occupies a week or so, begins almost as soon as the rise is completed – a 'short maximum'; sometimes it is delayed for several days during which the star remains at its brightest – a 'long maximum'. Long and short maxima commonly, although not invariably, occur alternately. Although an average period is not without meaning, the intervals between successive outbursts vary considerably, deviations of a third from the average length of the cycle being frequently observed. The longest well-attested mean cycle is that of about 270 days shown by UV Persei, while several stars have cycles of between two and three weeks. Many of the U Geminorum variables, especially those of the shorter mean periods, show additional peculiarities in their light curves. SS Cygni, the most extensively observed member of the group, sometimes has maxima with slow rises, and also exhibits occasional periods of great activity when it does not settle back to its normal minimum magnitude for months on end. Two other stars, AY Lyrae and SU Ursae Majoris, feature occasional 'supermaxima' in their repertoires – much longer and a whole magnitude brighter than normal maxima. Z Camelopardalis, which has a mean cycle of twenty-three days, normally exhibits only short maxima, as do

most of the other U Geminorum stars of such short period. Several times, however, it has been observed suddenly to suspend its fluctuations after declining part-way towards minimum, and then with equal abruptness, after months of inactivity, to resume its decline and continue its variations as if nothing had happened. Some other stars have also shown this phenomenon, but pride of place still goes to Z Cam, one of whose 'standstills' lasted 682 days – almost thirty times the mean period! The behaviour of Z Cam during the last few years has been even more anomalous. A satisfactory interpretation of the variability of these stars is still lacking: astronomers would be pleased to understand even the normal U Geminorum fluctuations, let alone the idiosyncrasies of the more pathological members of the group.

Probably allied to U Geminorum are the novae, which are not, as the name suggests, new stars but stars of perfectly respectable age which have brightened enormously in a temporary but violent outburst. Not a decade passes without some nova reaching naked-eye visibility, and five in this century have attained the first magnitude. Wherever adequate photographs taken before the outburst are available, they show an insignificant star, usually of rather unsteady brightness, at the position of the nova. In the outburst itself the nova brightens by as much as ten or twelve magnitudes, often within a few hours, although several interesting cases of 'slow novae' have been observed. The decline following the maximum is usually rapid and erratic at first and then less precipitate, and within a few years the normal nova has returned, so far as we can tell, to exactly its original state. The outburst seems, therefore, to be a rather superficial phenomenon which scarcely disconcerts the star as a whole, although spectroscopic observations leave no doubt that the surface layers of the star are blown permanently away into space by the explosion. A few novae have been seen to undergo more than one outburst; these objects display rather smaller ranges – about eight magnitudes – than most novae. Possibly all novae are recurrent, with cycles up to something like a million years, and represent U Geminorum variables of very long period.

Some red stars of very low luminosity show short-lived outbursts of up to about two magnitudes; the whole phenomenon is over in a few minutes, and is supposed to be similar in nature to a solar flare.

The most catastrophic form of outburst is that exhibited by the so-called supernovae. No supernova brighter than the seventh magnitude has appeared since the invention of telescopes, let alone spectroscopes, so that our knowledge of them is rather meagre. Nothing is known from observation about the initial state of the star; perhaps it finds itself internally in an impasse in which the mechanisms which normally regulate its rate of energy generation fail. Whatever the cause, the result is a titanic explosion which blows a large fraction of the mass of the star away into space at staggering speeds. For a few weeks what was once the star shines with the fierceness of a hundred million Suns; but a steady decline ensues, and in the end the scenes of all the supernova explosions witnessed by modern astronomy have been carried below the limits of detection in even the largest telescopes. Certain remarkable nebulae, however, are supposed to represent the material thrown off by prehistoric supernovae; and the Crab Nebula is identified with some certainty as the remnants of a supernova recorded by the Chinese in July 1054 as a temporary star rivalling Venus in brightness. A peculiar star of the sixteenth magnitude in the centre of the nebula is probably all that is left of the original star, while the cloud of rushing gases which surround it bears witness to the celestial catastrophe seen nine hundred years ago.

Meteorites and Life

M. H. HEY

For centuries men have speculated on the possibilities of life on planets other than the Earth, but as they had no information about conditions on the planets and little knowledge of the conditions essential for life, these speculations could be no more than wild guesses. Today we know much more of the physical and chemical conditions on the planets, and it has also become clear that life as we know it must be confined to a fairly narrow range of conditions. The old queries can now profitably be reopened – is there evidence that life could exist on any of the other planets or anywhere but on the Earth?

But though we can now say with fair confidence that life is impossible and probably always has been impossible on Mercury and is probably possible on Mars, we cannot say whether or not there is life on any planet other than Earth; we may soon have some direct evidence for the surface of the Moon, but at present the only extra-terrestrial material we can handle and examine in detail is in the meteorites, of which some 2,000, with a total weight of 200–300 tons, are known.

We do, indeed, know that the blue-green patches on Mars, the area of which increases in the Martian summer and shrinks in the Martian winter, could quite possibly be some form of plant life rather like the blue-green algae of Earth, but other possible explanations of these patches have been advanced, and until we can actually land some quite elaborate experimental gear on Mars no definite answer is possible. But with the meteorites it would seem at first sight a simple enough matter to decide whether or not they can afford evidence of extra-terrestrial life: unfortunately, it is by no means as easy as it would seem. As long ago as 1880

Hahn believed he had positive evidence: he interpreted certain structures that he had observed in meteorites as fossils, but his views have not been generally accepted. Again, fragments of a porous limestone were picked up near Bleckenstad in southern Sweden shortly after a prominent meteor had been seen. A. Hadding considered that these fragments were meteoritic; they have been regarded as evidence of extra-terrestrial life, although not all limestones are of biological origin; besides, there is very little evidence that the limestone fragments were really connected with the meteor.

Direct evidence of the existence of living bacteria in several different stony meteorites was offered by C. B. Lipman in 1932, but according to S. K. Roy his precautions against contamination were inadequate, and his bacteria almost certainly of terrestrial origin. Early in 1961, B. Nagy, W. G. Meinschein, and D. J. Hennessy, of New York, published results that they claim as evidence that the hydrocarbons present in a small class of meteorites are of biological origin, and later G. Claus and B. Nagy claimed to have observed 'organized elements' in the same class of meteorites, the carbonaceous chondrites; these elements they believe to be fossils of an extraterrestrial form of life resembling our algae. If these claims are substantiated, we have our first definite proof of extra-terrestrial life, and it is therefore essential to examine the evidence critically.

The carbonaceous chondrites are a small class – only twenty are known, out of nearly 2,000 different meteorites, and are peculiar in several ways. A few iron meteorites contain small amounts of carbon, as graphite, diamond, or iron carbide, and a very few stony meteorites contain diamond; but the carbonaceous chondrites are peculiar in containing hydrocarbons and other forms of combined carbon. They also contain hydroxyl-bearing minerals related to serpentine, often in considerable amounts; some contain free sulphur, some sulphates, and some nitrogen compounds. All show clear evidence of having been formed at quite low temperatures, whereas the great majority of meteorites are clearly high-temperature products. Their unusual and complex composition

and the fact that so little material is available combine to make the study of the carbonaceous chondrites particularly difficult, yet they are still the only material that could afford direct evidence of extra-terrestrial life.

Nagy, Meinschein, and Hennessy based their conclusion that the hydrocarbons in the carbonaceous chondrites are of biological origin on a comparison of their molecular structures with those of various biological products – fats and waxes. There is indeed a general resemblance, but it is not a particularly close one, nor has it been shown that a similar pattern could not have originated by purely inorganic reactions: the conclusion cannot be accepted as proven. The same applies to the 'organized elements'; many of them do indeed look remarkably like cells under the microscope, but that they are remains of living objects remains unproven. The 'organized elements' are mostly spherical or oval objects about 1/2000 to 1/5000 of an inch in diameter. Many of them appear to have an outer membrane like the cell-wall of many living organisms, and in a few this membrane appears torn or folded – but in some cases at least the object appears to consist of a mineral grain, probably of a serpentine, coated with a film that has not been identified but may consist of carbon compounds. A few of the objects are stained by the reagent generally used to locate nucleic acids in organisms – but this reaction does not necessarily imply the presence of nucleic acid or any other biological product, since we do not know just what carbon compounds will react with the reagent; and it is clear that a wide variety of complex carbon and carbon-nitrogen compounds can be produced by the action of ultra-violet and other radiations – the presence of 'organic chemicals' does not imply the pre-existence of organisms. At the time of writing several workers are studying the 'original elements', using a wide variety of methods, but it is still impossible to decide whether they are fossils or not.

If it ultimately turns out that the 'organized elements' and the peculiarities of the hydrocarbons of the carbonaceous chondrites can be explained without reference to life of any kind, the question whether life does, in fact, exist elsewhere than on Earth will still

remain open and unanswered. But should it be finally proved that these meteorites contain fossil remains, or products necessarily derived from living matter, or both, any theory of the origin and history of the meteorites will have to include a stage at which life was possible on or in them or the parent body from which they were derived. We are accordingly driven to consider what conditions are essential for life.

Life as we know it is based on the reactions of a small number of elements, of which carbon, oxygen, nitrogen, hydrogen, and phosphorus appear to be essential; many other elements are necessary (some only in very small amounts) to most living beings, but may not be strictly essential to all forms of life, as the above five appear to be. And since the various chemical reactions involved take place in solution, liquid water appears to be essential. (Liquid water outside the cell-wall of organisms that have a wall is probably not absolutely essential, but conditions must be such that the cell-contents are at least partly liquid. Some forms of life can survive freezing at temperatures at which no liquid water could be present, but they cannot grow or reproduce under such conditions; they can only survive, to grow again when conditions permit.)

It has, indeed, been suggested by J. B. S. Haldane that a form of life in which liquid ammonia takes the place of water might exist on Jupiter, and even that there might be life based on the reactions of molten silicates in the interior of the Earth. Our scanty knowledge of the chemistry of silicate melts and ammonia solutions suggests that neither is likely to give rise to a chemistry with anything approaching the potentialities of the carbon-compound-plus-water system. Whether either could give rise to anything we should call a living organism depends a good deal on how we define a living organism: a crystal can reproduce its kind so long as supplies of suitable material are available, but it is not alive; some viruses appear to consist of only a few kinds of molecule, and can even be crystallized – are they alive? A fully satisfactory definition of the term 'alive' is not yet available, though we have progressed a good deal towards one.

For our present purpose we will ignore other systems such as those suggested by Haldane and confine our attention to the carbon-compounds-plus-water system. In the solar system today, life could not exist on the surface of Jupiter or any of the outer planets, because all water would be frozen, while Mercury is much too hot (and probably lacks an atmosphere or water in any form). Conditions on the Moon are probably not compatible with life, at least not on the surface, because there does not appear to be more than a mere trace of atmosphere. Mars is just warm enough and has a reasonably dense atmosphere, so that conditions there seem quite suitable to elementary forms of life.

It is generally believed that meteorites come from the belt of asteroids, most of which lie between Mars and Jupiter, and which are usually believed to be the remains of a broken-up planet or planets of lunar size or larger; the few meteorites whose orbits have been determined were indeed typical asteroids of the eccentric-orbit type, like Eros, but it does not necessarily follow that the rare carbonaceous chondrites were asteroidal. Today, temperatures in the asteroidal belt are too low for life, and the geological evidence suggests that temperatures through the solar system have changed very little in the last 3,000 million years; before then, for most of the first 1,000 to 1,500 million years of the Earth's life, it seems likely that the Sun was a little cooler than today, and that the Earth (and *a fortiori* the outer planets and the asteroid planet) were too cold for life. If this is true, then life can never have existed on the surface of the planetary parent of the asteroids.

But if we assume that the composition of all the planets is much the same except for the most volatile elements (particularly hydrogen), any body of planetary dimensions must be at a high temperature inside, even if it condensed from a cold cloud of dust and gas. This heating arises partly from the gravitational energy of this expanded dust-and-gas cloud, which is converted into heat as it condenses, and partly from the breakdown of radioactive elements. It follows that although the surface of the supposed planetary parent of the asteroids and meteorites was most

probably too cold for life, there would be a zone within the crust of the planet where the temperature would be favourable.

There is, however, a second problem: all life on Earth today is ultimately dependent on energy received from sunlight, and so, almost certainly, is any life there may be on the surface of Mars. Any form of life within the crust of a cold-surfaced planet must necessarily derive its energy from some other source; and on this point we can say no more than that other sources would probably be available. Thus it is conceivable, on the data we now have available, that some form of life might have existed on the hypothetical planetary parent of the meteorites.

Finally: if life does, or did, exist on any other planet of the solar system, does this help to account for the origin of life on Earth? It is difficult to see how it helps, since it seems fairly clear that conditions on Earth are more favourable to life of the carbon-compounds-plus-water kind than any other planet. Either life developed naturally and inevitably on Earth just because conditions were suitable, or, if it was brought to Earth from outside, it seems almost certain that it must have come from outside the solar system altogether. This is the 'panspermia' hypothesis of Arrhenius; there are other planetary systems in our galaxy and other galaxies in the universe, and it is quite conceivable, indeed probable, that life exists or has existed on other planets in other systems. It is conceivable that elementary forms of life might be carried high in a planetary atmosphere, to escape into interstellar space, and might survive dehydration and intense cosmic-ray bombardment for millions of years, ultimately to reach another planet on which conditions for life were favourable. But it seems far more likely that life will originate wherever conditions are favourable and remain favourable for long enough.

The Surface of Venus

PATRICK MOORE

Venus has often been called 'the Earth's twin'. This is not unreasonable, since in mass and dimensions Venus resembles the Earth much more closely than any other planet; the diameter is 7,700 miles, whereas that of Mars is a mere 4,200 miles. The escape velocity of Venus is 6·3 miles per second, as against the 7 miles per second for Earth; the distance from the Sun amounts to 67,000,000 miles, while that of our own world is approximately 93,000,000 miles.

We might therefore expect that Venus and the Earth would be in a similar state, and early telescopic workers were entitled to hope that they would be able to see surface details – as is actually possible in the case of Mars, for which accurate maps have been drawn. Unfortunately, the true situation is very different. Nobody has ever seen the surface of Venus; the planet is permanently hidden by its atmosphere, and all we can examine is the upper part of the 'cloud' layer.

Careful observations reveal faint, diffuse shadings on the brilliant disk, but these are impermanent, and are not noticeably informative. There seems to be no chance that they are due to protruding mountain-tops or plateaux, as has been suggested in the past. With regard to the surface conditions, then, we have to base our conclusions upon indirect methods.

The composition of the atmosphere is all-important. Thirty years ago W. S. Adams and T. Dunham were able to show, spectroscopically, that the chief constituent is carbon dioxide, which exists in great quantities. Until recently it was believed that water vapour must be absent, since spectroscopic investigations had failed to reveal it; and free oxygen, too, was rejected (though

naturally there was known to be plenty of oxygen bound up with carbon in the carbon dioxide, the chemical formula for which is CO_2). In fact, the atmosphere of Venus was thought to be extremely unfavourable for life in any form.

A further point is that carbon dioxide tends to act in the manner of a greenhouse, and blankets in the Sun's heat. This, together with the fact that Venus is closer to the Sun than we are, would presumably lead to a very high surface temperature, and Venus was generally dismissed as a desert world without a trace of moisture – an arid, lifeless dust-bowl. Space-travel enthusiasts had every excuse for concentrating their main hopes upon Mars, which, forbidding though it may be, is not overwhelmingly hostile.

Before going any farther, it may be as well to pause briefly in order to discuss a question which is bound to affect our views about the surface conditions. This concerns the length of Venus's 'day'. The axial rotation period of Mars is known very precisely, because its surface details are visible; but no observations of such a kind are possible with Venus. The diffuse shadings are mere 'cloud' phenomena (remembering that the word 'cloud' must be used in its broadest sense), and are too vague and impermanent to be helpful.

Mercury, the innermost planet, has a 'captured' rotation; that is to say, it completes one turn on its axis for each revolution round the Sun – 88 Earth-days. Mercury therefore keeps the same face to the Sun all the time, just as the Moon does with respect to the Earth. There are various complications, and there is a belt on the surface of Mercury over which the Sun would seem to rise and set, but the general principle is clear enough.

Schiaparelli, an Italian astronomer of the late nineteenth century who paid a great deal of attention to the planets, believed that Venus, too, had a captured rotation, so that the 'day' and the 'year' would be equal at 224·7 Earth-days. However, this idea is not borne out by temperature measures. In the United States, W. M. Sinton has found that the temperatures of the bright and dark hemispheres of Venus are about the same, which would

hardly be the case if one hemisphere were in permanent daylight and the other plunged into perpetual night. We are therefore justified in assuming that the rotation period is less than 224·7 days.

Unfortunately, this is about the only conclusion which seems safe! We have to confess that so far we have no real idea how long Venus takes to spin on its axis. Recent Russian results give a period of 10 days; G. P. Kuiper, in the United States, gives about 30 days; J. D. Kraus prefers only 22¼ hours – and so on. If we accept Kuiper's value, there can be only 7 or 8 'days' in the planet's 'year'.

Until we know more about the composition of the atmosphere at low levels, we cannot even begin to draw up a wind-chart; but if the rotation period is long, amounting to something like a terrestrial month, the winds may be comparatively strong and regular. Neither can we tell whether mountains exist on the surface. There is no evidence for them – but neither is there any positive evidence that they do not exist.

Forty years ago it was believed that Venus must be a tropical, moist world, perhaps similar to the Earth in Carboniferous times and possibly with the same sort of life. The analysis of the atmosphere caused a change of view, and the unattractive desert picture took its place. Then, however, D. H. Menzel and F. L. Whipple, in the United States, proposed a new theory, according to which Venus would be completely covered with water.

Support was forthcoming when new studies were undertaken by means of balloon ascents. The only way to prove the existence of water-vapour on Venus is to detect it in the planet's spectrum—and this is a difficult matter when observations are carried out from ground-level, since any traces of water-vapour on Venus are masked by the effects of the water-vapour in the Earth's own atmosphere. From a balloon, however, matters are easier, since the examination can be made from a point above much of the Earth's atmosphere. In this way it has been shown that there is a great deal of water-vapour in the atmosphere of Venus, and the Whipple–Menzel picture therefore appears to be more plausible than the dust-desert, though the whole question is still very open.

Theoretical work carried out by B. Warner, in London, shows that there may also be a certain amount of free oxygen. Very recent reports from Russia state that some Soviet workers have come to the same conclusion.

This does not mean that the atmosphere of Venus could be breathed by Earth-type creatures, but it does indicate that conditions there may be less hostile than appeared likely a few years ago. Much will depend upon the surface temperature, which may or may not prove to be hopelessly high.

If we follow the marine theory, there is, however, a loophole for the existence of some sort of life. It may be worth drawing a parallel with our own world—not the Earth as we know it, but the Earth as it used to be 500 million years ago, in the period known to geologists as the Cambrian. In those far-off times, the atmosphere contained more carbon dioxide and less free oxygen than it does now. Later, plants spread on to the continents; and by the process known as photosynthesis these plants removed much of the carbon dioxide and replaced it with free oxygen. If a modern man could go back in time to the Cambrian Period, he would be unable to breathe, because the atmosphere of the young Earth was of the wrong type.

Yet even in the Cambrian, life had already begun in the Earth's oceans, and lowly sea-creatures existed. As the years passed in their millions, the tiny marine organisms evolved slowly into fishes, amphibians, reptiles and mammals, ending up as men. It is at least possible that conditions on Venus now are comparable with those which prevailed on Earth during the Cambrian Period. If so, life there may follow the same pattern as it has done here, and intelligent beings may eventually develop.

The whole theory is, of course, highly speculative, to put it mildly. We may be wrong in supposing that Venus has extensive oceans; further research may show that the desert picture is right after all. Alternatively, both may be very wide of the mark. The most we can say at the moment is that advanced life on Venus is highly improbable, but that we cannot rule out the existence of lowly marine organisms.

We must admit, too, that conventional astronomy gives us very little hope of clearing the matter up. Visual work is of limited value, and even detailed photographic and spectroscopic researches have been largely fruitless; Venus guards its secrets well. If we are to find out what the planet is really like, we must pin our faith in space research methods.

The first rocket to Venus was launched by the Russians early in 1961. All the evidence shows that it passed within 65,000 miles of the planet during May of that year, but precise information is lacking; the transmitters in the vehicle failed at an early stage, so that all track of it was lost. However, further probes of the same kind are being planned in both the U.S.S.R. and the U.S.A., and there is every chance that they will be successful, though it will be far from easy to collect and analyze the information which they gather.

Manned flight to Venus lies much farther in the future. A journey will take months to complete, instead of only a day or two in the case of the nearby Moon, and it must be many years before the first attempt is made. Yet if we continue to progress, and avoid further senseless warfare, we may expect men to reach Venus within the next century or two. Whether the planet will prove a fit site for a permanent or semi-permanent base remains to be seen.

What will the first explorers find? Will they land in a dust-desert, with a fiercely hot climate and constant winds of hurricane force, or will they land upon a world where there is almost no land at all, but where the surface is covered with great oceans containing primitive life? So far we cannot pretend that we know enough to give even a rough guide. Venus is the nearest planet to our own world, but it is also the one planet about which our ignorance is practically complete.

A Run-off Observatory

HENRY BRINTON

The problem of housing a medium-sized telescope presents something of a challenge to those who are neither rich nor gifted with the natural genius of the handyman. I am a fit person to write on the subject, because I am the owner of a 12-inch reflector, and I am neither affluent nor dexterous. It is broadly true that if I can solve the problem, anyone can.

The simple answer for those incapable of building a revolving dome – and those who have such skill will not need advice – is the run-off shed. Very little craftsmanship is needed to make one which will fulfil the three requirements of this form of protection for a valuable telescope. It must give adequate cover, be easy to remove and cheap to build.

In my view, there is everything to be said for using tempered hardboard for the principal material. It is cheap to buy, costing only ninepence a square foot, and will stand up to the weather well. My own telescope is housed in a sunken garden within a hundred yards of the open sea, with nothing but a hedge to keep off the winds, or more usually gales, which come straight from South America, laden with corrosive brine and abrasive sand. With a single outside coat of bitumenous aluminium paint, the board shows no signs whatsoever of yielding to these challenging conditions.

Another prime advantage for the clumsy-of-hand in using hardboard is that each wall of the shed is semi-rigid in itself by the mere process of cutting it out to the right size. If weather-boarding is used, rigidity is secured only by accurate and sturdy fastening.

For a 12-inch or larger telescope, the board should be fixed on 2 inch by 2 inch sawn joinery softwood along all the edges,

crossed, if necessary with 2 inch by 1 inch for extra rigidity. For smaller telescopes, 2 inch by 1 inch may be strong enough throughout. It is as well to creosote the wood after cutting, but before joining and nailing or screwing on. As the wood is liable to go first at the joins, treating at this stage will protect the most vital parts.

Because the wood is principally there for the purposes of giving extra rigidity and joining the sides, there is no need for neat joints; the board being nailed or screwed on to the wood will keep the battens in place. A simple joint for joining the top and end supports can be made by cutting out half the thickness of the batten at each end, and then nailing one over the other to fit flush.

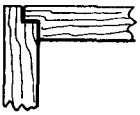

Fig. 1.

It is impossible to suggest actual dimensions, because each instrument has its own, often odd, shape. The only essential is that the roof should be sloped sufficiently to allow the rain to run off easily; 15 degrees is quite sufficient.

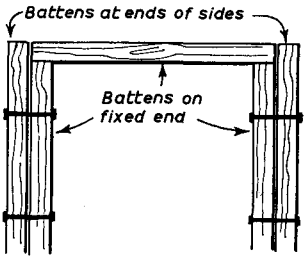

Fig. 2.

The hardboard comes in sheets 12 feet by 4 feet, and it is therefore necessary to have joins. Needless to say, it is most important to fix a batten behind the joins; but, for the roof particularly, just nailing the board to the wood is not sufficient. Before putting the batten in place for nailing, it should be laid with a strip of sealing compound to come immediately under the join. Selastic, or almost any of the other proprietary seals, will make a good, waterproof

join if applied in this way. Otherwise it is miraculous how the water will find its way through.

The run-off shed consists essentially of three fixed sides, a roof and a door. The simplest way of going about the construction is to make and erect the three fixed sides first. Each side will consist of a sheet of hardboard, fixed on battens, as described. One side is, of course, lower than the other, to allow for the pitch of the roof, and the fixed end has to be tailored to fit the two sides. The actual design and method of fastening will have to be decided in the light of the dimensions of the individual telescope.

The fixed end can be fastened on to the sides in a number of different ways. One simple one is to make the battens of the fixed end fit snugly inside the battens of the two sides, and then bolt or nail the two sets together. This, though fairly firm, will not be quite firm enough for larger sheds. For these, small diagonal pieces can be fixed across the corners at top and bottom, their size being dependent upon the amount of clearance in any individual case.

The open end, where the door is to be hung, presents a less easy problem, since, by its nature, it can have no support whatsoever across the bottom. If it were not that the rails, to which we will come presently, prevent the sides splaying outward, a run-off shed for anything but a small telescope would be impracticable. As it is, it is necessary to design the whole shed to allow sufficient clearance to permit small diagonal supports across the corners from the sides to the roof.

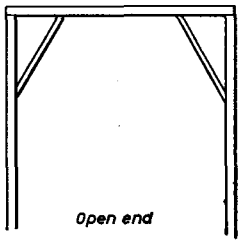

Fig. 3.

The roof itself is a critical part of the construction, since it must be absolutely waterproof both in itself and where it joins the walls. If it is to be more than 4 feet wide, the joint should be most carefully made, and the board nailed closely over well-applied sealing compound. Unless the shed is very large, the board can be fastened straight to the battens running along the tops of the three fixed sides, with its own battens cut to fit closely inside these. A couple

of inches at least of overlap of the roof board should be left all round. When it has been fixed, flat pieces of board, 3 inch by 1 inch or $2\frac{1}{2}$ inch by $\frac{3}{4}$ inch, should be pushed up tight against the overlap of the roof and nailed on to the battens of the sides with sealing compound in the joint.

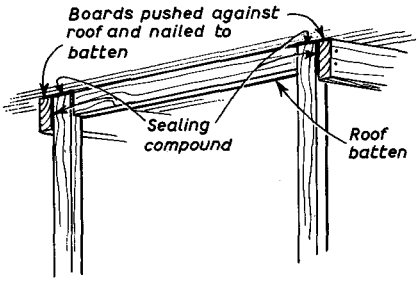

Fig. 4.

The door is largely a matter of choice. There is little or nothing to be said for hingeing it. Whether or not it is divided, a hinged door will only flap and swing and get in the way when the shed is pushed back. Much the best plan is a door which will simply lift off, though, if it is big, it can be a nuisance in a wind, acting as a sail which will suddenly carry off the observer if he is unwary. On the other hand, few of us have telescopes rigid enough to be much use in a high wind.

A door which lifts off can be made like the lid of a box. The top and side battens of the shed can be flush with the board, and the door have battens which fit outside these, like the rim of a box lid. Better, I think, is to let the boards of the shed stick out beyond the battens and let the door fit inside, with its own battens lying up against the battens of the shed. Any form of fastening can then be made, either round the outside, or through the two pairs of battens.

So much for the shed itself. The next question is the method of running off. The essentials are, naturally, some wheels and rails. Wheels are fairly easily come by, made of some hardened rubber

compound, 5 inches in diameter with 1-inch axles, intended for fitting on trolleys. They can be bought at most large ironmongers'.

A simple way of fitting the wheels on to the bottom of the sides of the shed is to have pairs of plates cut and drilled by a blacksmith. Through two holes in the top, the plates can be bolted on either side of the 2 inch by 2 inch running along the bottoms of the sides

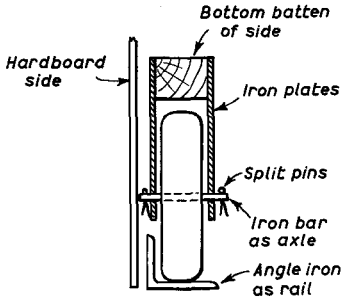

Fig. 5.

of the shed. One-inch holes, drilled opposite one another in the bottoms of the plates, can take a simple piece of steel bar to form axles for the wheels. The axles can themselves be held in place by drilling small holes through the ends of the bars and inserting split-pins when the wheels are in place.

It remains to provide rails. Builders' merchants can sometimes produce rails intended for sliding garage doors; but these are not easy to find, because most garage doors are now hung, or else roll. In any case, the rails tend to be expensive. A simple solution is to use ordinary $1\frac{1}{4}$-inch angle-iron, which makes excellent rails and is as cheap as possible.

Naturally, the rails need fixing, the strength and closeness of the fasteners depending upon the nature of the ground. The easiest method, if you have a friendly blacksmith close at hand, is to get him to weld a number of rods or strips along the bottoms of the angles. The perfect way of laying is to sink each of these in a concrete pocket, in which case spiral strips should be used. If the

ground is firm clay, it is enough to have rods 6 inches long pushed into the clay. Most builders' merchants can now provide ready-mixed cement in small bags, so that laying the cement pockets is an easy matter. In either case, the most essential matter is to make sure, by using a gauge, easily made of wood, that the rails are truly parallel *and* the right distance apart.

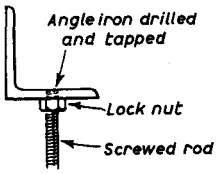

Fig. 6.

If a blacksmith is not available, simple fasteners can be made with threaded steel rods, which are very easily bought. This involves drilling and tapping a number of holes along the rails. When this is done the rods must be screwed to the underside of the rails, so that the tops of the rods are flush with the surface of the rails. Lock-nuts must then be pulled up tight on the underside.

It goes almost without saying that the boards of the sides are continued down beyond the 2 inch by 2 inch battens which carry the wheels. Hardboard is quite rigid enough for this; but slots will have to be cut to allow the axles to protrude slightly. In addition to this, it is very desirable to screw or bolt on both sides a single piece of iron strip to the 2 inch by 2 inch on the outside and bend it inwards slightly, so that it will just rub the edge of the rail. In this way, the unsupported front ends are prevented by the wheels from splaying outward and by the strips from splaying inwards.

One last point may need to be taken care of. If the shed is narrow in relation to its height and length, there may be danger of it blowing over in a high side wind. My own shed is broad, and has shown no signs of yielding to even a furious gale; but narrower ones may be less secure. There are many easy ways of dealing with the problem; but the first consideration is that any fastening should be quick to release. There are enough things to fiddle with in preparing the telescope without wantonly adding to the number.

A very easy solution is to sink a metal rod, with a loop or ring on top, in the ground on each side. If hooks are then fastened to the sides of the shed, they can be so arranged that they will slide

into the rings automatically, and so anchor the shed without the need for any action.

A run-off shed can be made easily and cheaply in this way. When it is time to use the telescope the door is unfastened and lifted away by handles screwed to the outside; a push, and the shed rolls away – and the telescope is all ready to be used. When observing is over, a simple push; the door lifted on and clipped; and the instrument is snugly and safely housed for any length of time and in any weather.

Stellar Clusters and the Cosmic Time Scale

P. G. MURDIN

It has long been realized that the stars are not distributed in a random way. A cursory examination of the night sky shows that the stars are concentrated towards the Milky Way: we are, in fact, within a lens-shaped system of stars called *the Galaxy*. There are many millions of other similar galaxies or stellar systems besides our own; the Andromeda "Nebula" (M 31) is a well known example.

Even within this lens-shaped system, however, the stars are not grouped at random. They fall together in twos and threes, and more populous groups contain perhaps two dozen to a few hundred stars. These are termed *galactic clusters*. Outside the Galaxy, too, yet associated with it, are more star-clusters which contain tens of thousands of stars. These clusters are called *globular clusters* because of their tight spherical appearance: they are totally different in structure from the looser and very varied galactic clusters.

Two typical galactic clusters can be seen in the autumnal night skies: the Pleiades and the Hyades. The bright stars of some constellations, such as the Plough, Taurus, Orion and Perseus, form clusters which are not so obvious, because we are so near to them that the component stars are widely separated in angular measure. These components can be recognized as being near one another in space because of their common motion. Other constellations are made up of stars which are unrelated but which happen to lie in the same general direction; for example, Cassiopeia, Lyra or Aquila.

Globular clusters are not so easily seen with the naked eye as

the galactic clusters, since they are usually much farther off. The two brightest are Omega Centauri and 47 Tucanæ, unfortunately both invisible from these latitudes. The brightest globular cluster visible from Britain's latitudes is M 13 in Hercules. If its position is accurately known it is faintly visible as a hazy patch to the naked eye. A moderate-sized telescope will resolve this patch into at least some of its component stars. Altogether, about half a dozen globular clusters and about a score of galactic clusters are visible under very good conditions to the naked eye. About 150 globular clusters and 500 galactic clusters are known in the Galaxy. Other galaxies are known to be surrounded by globular clusters, notably M 31 and the Magellanic Clouds.

The Distance of the Clusters

Globular clusters are all very much the same in size and composition, although subdivisions are to be recognized. Their central region is about 15 light-years (l.y.) in diameter, but stars associated with the cluster may be found at distances as great as 50 l.y. from the centre. The assumption, justified by practice, that the globular clusters are of the same real diameter was applied by Shapley to calculate their relative distances by measuring their apparent diameter. The distances of the clusters from the Sun are inversely proportional to the angular diameters if the clusters are all the same size.

A second way of finding the distance of a globular cluster from the Sun is to measure its apparent brightness and, by means of the known classification of cluster types, to estimate its actual (*absolute*) brightness. A comparison of the two brightnesses will thus give the distance of the cluster. A better way of finding the distances of the clusters is to compare the brightnesses of individual stars within the clusters, but this method can only be used for near clusters where the stars are resolved. Shapley used a method which is statistical: he assumed that the twentieth most bright star in each cluster was of constant magnitude from cluster to cluster and, comparing this with the observed magnitude, deduced the relative distance of each cluster. In his investigations he also used the

variable stars which are found within the clusters and are sometimes called 'cluster variables'; but as they are found elsewhere than in clusters *RR Lyræ stars* is a better designation, RR Lyræ being the prototype. The variable stars have a known absolute magnitude ($M = 0$, almost exactly), and hence their distance can be deduced rather precisely. They are also easy to pick out from the other stars in the cluster, if the cluster is near enough.

These four methods can be compared among themselves and with other standard methods for determining distance in astronomy. They are remarkably consistent, a fact which encourages belief in their reliability. Shapley's results are essentially those used today, with some corrections to allow for the absorption of light in the interstellar medium.

The results show that the distances of the globular clusters are between 20,000 l.y. and 250,000 l.y. from the Sun. For comparison, the distances of the galactic clusters lie mostly within the range 1,500 l.y. to 15,000 l.y.; their dimensions vary between 10 and 80 l.y. The distances of the clusters were in themselves remarkable enough, as they gave astronomers a new scale to grasp, distances which were much greater than any before contemplated. But it also transpired that the globular clusters were outside the Galaxy, which was at that time thought to comprise the totality of the Universe. Moreover, while the galactic clusters are concentrated strongly within the disk of the Galaxy – Miss Helen Sawyer Hogg has called them the 'backbone of the Milky Way' – the globular clusters form a spherical system whose centre is about 28,000 l.y. away from the Sun in the direction of Sagittarius. This positioning is only to be explained if the galactic centre, around which the clusters are concentrated, is in this direction. The Sun is therefore not at the centre of the Milky Way system, as had been assumed before, but displaced some 28,000 l.y. to one side. This has been amply confirmed by both optical and radio astronomy. The radio map of the Milky Way shows a strong condensation towards Sagittarius which undoubtedly comes, at least in part, from the galactic nucleus.

Stellar Populations

While investigating M 31 with the 100-inch Mount Wilson reflector under the good conditions afforded by the black-out of the nearby city of Los Angeles during the war, Baade discovered that groups of stars could be divided into two classes which he termed Population I and Population II. Objects of Population II were composed mostly of red stars: typical members of Population II were centres of galaxies and the stars between the spiral arms. Population I objects were mixed, but made of characteristically blue stars. They were found, with large amounts of dust and gas, within the spiral arms of galaxies. (The distinction between populations is not clear cut: each population merges into the other, but the classification is of great convenience and meaningful.) Because of this distinction between the galactic nucleus and the spiral arms, one may anticipate from their contrasting distributions that galactic and globular clusters will differ in their stellar composition, each being composed of a different population. This is indeed the case. The stars of a globular cluster are red and such clusters contain very little interstellar material (if any). They are therefore typical Population II objects. The galactic clusters contain large amounts of interstellar material and the bright stars tend to be blue (e.g. the Pleiades) or yellow (e.g. the Hyades). They are typically Population I.

The physical difference between the two populations is now quite well established. The Population II stars were formed a long time ago – in the case of the globular clusters, probably from a catastrophic condensation of the same dust and gas cloud which formed the galactic nucleus. In Population I objects, on the other hand, the star-forming material is still present and stars are slowly forming out of it. Population I objects are therefore composed of stars of all ages.

One may expect the Population II globular clusters to be old objects of approximately the same age, while the Population I galactic clusters are of different ages, mostly younger than the globular clusters. This conclusion is supported by independent

evidence from the *colour-luminosity diagrams* of galactic and globular clusters.

The Colour-luminosity Diagram

The colour-luminosity diagram was invented independently by Hertzsprung and Russell and is sometimes called after them. The diagram consists of a graph on which each star is represented by a point whose co-ordinates are luminosity and colour. The luminosity is the actual total energy given out by the star, but a convenient approximation is the absolute visual magnitude. A quantitative measure is given to the colour of a star by taking the difference between the magnitude of the star in different parts of the spectrum, that is, in blue and in red light. This difference is called the *colour index* of the star. It is essentially a measure of the temperature of the star's surface. Red, cool stars have a positive colour index; hot, blue ones a negative one.

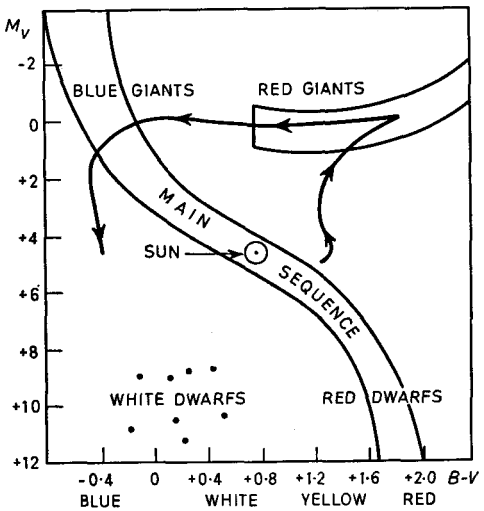

Fig. 1. The colour-luminosity diagram (simplified). M_V is the absolute visual magnitude, B—V is the colour index. A typical evolutionary track of a star somewhat fainter than the Sun is marked. (Diagram by Frank Whitford.)

When a large number of stars is plotted on this diagram, the curious fact emerges that not all the parts of the diagram are inhabited. The points concentrate mostly in a band which stretches from lower right to upper left, that is, from red dwarf stars to blue giant stars (see Fig. 1). This band is called the *Main Sequence*. There is also a populous region in the top right-hand corner, called the red giant area, since it is occupied by bright red stars. A sparsely populated region occurs in the lower left corner. Its inhabitants are called white dwarfs.

The significance of the diagram is as follows: a cloud of interstellar matter will contract under its own gravitational influence and the influence of radiation pressure from the surrounding stars to form an embryo star. As the star contracts the temperature of its centre rises – as the temperature of any contracting gas does – until it reaches that certain value at which nuclear reactions can occur. The star then starts radiating light energy and stops contracting – it becomes a stable star. It is then represented by a point on the Main Sequence. The Main Sequence, therefore, represents stars which have just formed from the interstellar medium; the only difference between parts of the Main Sequence is that some stars are heavier than others, depending on the size of the dust and gas cloud which started contracting. Heavier stars are represented by points higher up the Main Sequence. When a certain percentage of its nuclear fuel is burnt (about 15 per cent) the star becomes unstable and starts to expand off the Main Sequence. It then quickly follows an evolutionary track into the red giant region and then across to the blue giants. (This track is drawn in on Fig. 1). So far the course of the star on the colour-luminosity diagram is well understood (at least in principle). Why the next stage happens is not known, but somehow the blue giant star collapses into a white dwarf, at which stage, to all intents and purposes, it is dead. It ceases to give out much energy and hence cannot be seen very easily (this is why the white dwarf area of the colour-luminosity diagram is sparsely populated).

The point in time when the star becomes unstable and begins to expand depends on the mass of the star, the heavier ones

becoming unstable first because they consume their nuclear fuel at a greater rate. If therefore we have a collection of stars which were all formed *at the same time*, some proportion of the bright heavier ones will have lived their life and died: they will no longer be visible. The stars which are slightly lighter than these will be in various stages of evolution in the red and blue giant stages. The lightest stars of all will be on the Main Sequence, since they will still be stable stars, consuming their nuclear fuel at a steady pace.

Now, in the stars of a globular or a galactic cluster we have precisely such a group. The probability of a large number of stars of different ages coming together by chance is entirely negligible:

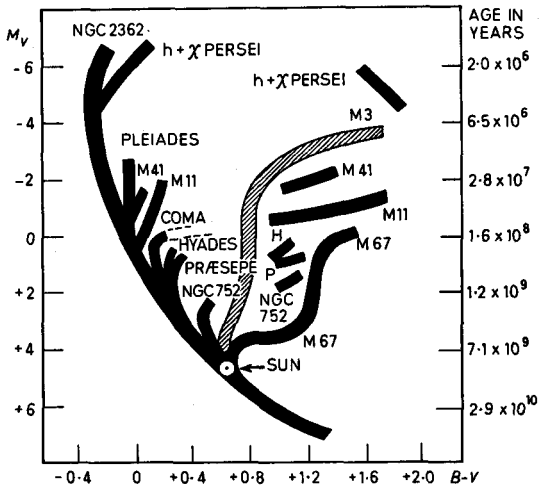

Fig. 2. The colour-luminosity diagrams of ten galactic clusters and one globular cluster (shaded) superimposed. The age corresponding to various Main Sequence turn-off points is along the right hand ordinate. (Diagram by Frank Whitford, after Allan Sandage, 'The Colour-Magnitude Diagrams of Galactic Clusters and their interpretation as Age Groups', Stellar Populations, *The Vatican Observatory* (1956).)

the stars of a cluster must have been formed from the same dust cloud at the same time by a catastrophic condensation. Thus the members of a cluster will form a colour-luminosity diagram just

like the one mentioned above. Heavy stars will have died; light ones will still be stable on the Main Sequence; and stars of intermediate mass will be scattered in the blue and red giant regions. This is precisely what is observed. The colour luminosity diagrams for a number of different galactic clusters and one globular cluster are plotted in Fig. 2. (Only one globular cluster can be plotted since these clusters are not so easy to observe down to the critical turn-off point.) From this diagram we can deduce the ages of the various clusters. We can find from the turn-off point of the Main Sequence the mass of a star which is just beginning to expand into the giant stage. Stellar theory tells how long it takes a star of that mass to begin the expansion process. This is the age of the cluster. The age corresponding to various turn-off points is plotted on the right-hand axis of Fig. 2.

It is thus apparent that a typical globular cluster may have an age of say 6×10^9 years, and that the ages of the galactic clusters range from 0·1 to 10×10^9 years. These figures are independently supported by calculations based on the gravitational stability of the clusters. The stability of a cluster depends critically on its mass: the stars of a large cluster will tend to hold one another together, although if two stars approach closely one may be thrown from the cluster. Loose clusters, on the other hand, are not so massive, so they not only disrupt themselves, but are disrupted by the gravitational field of the Galaxy. (The Galaxy does, of course, have an action upon the compact clusters; this effect, however, is not so noticeable.) Expanding clusters have been found observationally, the Zeta Persei cluster being an example. Some clusters are slightly ellipsoidal, showing the gravitational influence of the Galaxy. The rate of evaporation of loose clusters has been calculated by Chandrasekhar, who finds that the Pleiades will lose half its stars in about 2,000 million years (2×10^9 yrs). The Hyades will lose a similar amount in 3,000 million years and a very loose cluster such as that including five stars of the Plough will disintegrate in, say, 500 million years ($0{\cdot}5 \times 10^9$ yrs). These figures confirm in order of magnitude, if not in detail, the figures based on the evolutionary theory of stellar physics.

Thus far this inquiry may imply that astronomers have completely solved the questions of stellar evolution and the ages of stellar clusters. Nothing could be farther from the truth. Although astrophysicists are confident to a degree that they are at last on the way to a complete solution of the problem of stellar evolution, there are still many difficulties – if not in areas of complete mystery like the white dwarf transition, then difficulties of detail. Dicke has recently stressed the point that some galactic clusters appear, on the latest measurements, to be older than the Universe! He has based an entire cosmological theory on this, its distinguishing feature being a decreasing gravitational constant. Thus the figures for stellar ages will be considerably reduced – stars will effectively be heavier in their early stages and will consume nuclear fuel at a faster rate. This apparently *ad hoc* theory of a changing gravitational constant does have some scientific basis: it can be made to arise from general relativity.

The fields of astrophysics and cosmology have thus grown together in an attempt to explain the structure of the Universe. As Couderc has said: 'The elements of duration and evolution are inextricably associated with our perception of the Universe.' This area of investigation is by no means exhausted: our perception needs yet to be refined.

Astronomy as a Career

E. A. BEET

What does this title imply? There is probably some kind of mental picture of a man busy with a great telescope in the small hours, looking at objects of his own choice because they are of interest to him – and then, no doubt, staying in bed for much of the day! The youngest aspirants to this career probably have a picture which includes also space ships and lunar exploration at first hand. Both pictures have a false glamour about them, picking out the highlights (actual or speculative) and neglecting the more ordinary things which make up most of life. Astronomy is probably one of those careers which attracts many but suits few, and it is one for which, in comparison with most professions, few are needed.

What is an astronomer? This is not an easy question, because it is becoming increasingly difficult to isolate one branch of science from another. Consider one straightforward astronomical project. A physicist will have designed the optical system of the instruments and engineers and technicians will have made them. An astronomer (no difficulty at this point) will direct them to the desired region of the sky and take the photographs. The photographic emulsion and the subsequent processing are fruits of the labours of chemists. The examination and measuring of the plates is physics again, possibly involving the use of electronic equipment, and the resulting measurements may then be passed to a mathematician for statistical analysis. If we take 'astronomer' to mean anyone employed in an astronomical observatory, then it is clear that he must be a man of many parts, though he is likely to be a specialist in some particular aspect of the work. It has been one of the duties of the present writer as an officer of the British Astronomical Association to answer astronomical queries of many

kinds. A recent one was this: 'How is it that so many Professors of Astronomy have, according to the biographical dictionaries, been appointed to their professorial chairs *without* having taken their degree in astronomy? They have all been graduates in mathematics, it is true, but how does that qualify them to hold a chair in astronomy?' The would-be astronomer must, of course, have a deep interest in astronomy, but need not have academic training peculiar to it. He must have the attitude of mind and dedication to learning which is cultivated by a training in mathematics and one or more of the physical sciences; that is, he must be a scientist first and an astronomer afterwards. Boys and girls (the profession is open to women on the same terms as men) still at school and contemplating astronomy should concentrate on such subjects; they are the key to astronomy, and to many other things if the first choice is not achieved.

In the United Kingdom astronomers have two main sources of employment, the universities and the Government observatories. Astronomy departments are maintained at the Universities of Cambridge, Oxford, London, Manchester, Edinburgh, Glasgow and St. Andrews. The State-supported observatories are the Royal Greenwich Observatory at Herstmonceux (one of the largest establishments in the world), the Royal Observatory at Edinburgh, and, as a southern counterpart to these, the Royal Observatory at the Cape of Good Hope. The Government of Northern Ireland maintains an observatory at Armagh. Independent observatories have almost vanished; the only one that comes to mind at the moment is the combination of the Jeremiah Horrocks and Wilfred Hall Observatories run for educational purposes by the Borough of Preston. In Eire there is the Dunsink Observatory of the Dublin Institute of Advanced Studies. It is not unusual for British-trained astronomers to be appointed to observatories overseas, as, for instance, in Australia and South Africa. Establishments for the pursuit of radio astronomy are increasing in number. At present they are at Cambridge, Manchester and Sheffield Universities, the Radio Research Station at Slough, the Royal Radar Establishment at Malvern and the G.P.O. Research Station. Those who fail to

obtain an appointment in pure astronomy may be able to use their interest and training in allied topics such as geodesy, upper-air research and rocket research, and a man who has studied radio astronomy might find an opportunity in the radio industry itself. On the face of it there are a lot of openings for potential astronomers, but it must be realized that not all the staffs are large and not all the members of a staff are practising astronomers. Giving an astronomer a working life of forty years, only two or three per year will be retiring from each hundred appointments. Vacancies are not very numerous and the standards of entry, of which more later, are consequently quite high.

An astronomer's routine is bound to vary from one observatory to another. In a university department there is some lecturing to be done, students' work to supervise, essays to correct and so on, but this will not apply to a purely research establishment. In both places, however, there will be prescribed programmes of work to be carried out, and in both there will be some opportunity for the more senior members of the staff to carry out some research of their own. Apart from the teaching side, the astronomer's work can be divided into three parts, observation, laboratory work with measuring machines and the like, and computing; there will also be reports to write up. Some appointments may be more for one aspect than another, but it can be assumed that some of all three will fall to the person or persons working on a particular programme. The night work is spread over the staff, three or four nights a week with compensatory time off during the day, and those undertaking it must live at or near the observatory. The observer may be lucky, in getting an early start and having an unbroken spell of several hours to see the job through. On the other hand, bad weather may delay or interrupt a piece of work which, when started, must be completed or else it will be entirely wasted, meaning that he has to hang about for hours to get thirty useful minutes. On bad nights, if there is the slightest hope of a clearance he must report for duty, or 'sleep in' if there are facilities for doing so. Clearly the astronomer must not have a possessive wife who cannot let him out at night! She will have to give him

up for months on end if he has the good fortune to be selected for an eclipse expedition to some remote part of the world. Sometimes an astronomer is sent to work at a foreign observatory where there are essential facilities, either of site or of equipment, not available at his home station. Off-duty, the university astronomer has the social life of the town and university available to him; a great establishment like Herstmonceux, situated out in the country, provides sports clubs and social amenities on the spot.

To become a university astronomer the candidate must first get into a university, and the minimum qualification for entry is the General Certificate of Education including two subjects at the Advanced Level. So many applicants, however, can offer three that three 'A' levels has become the practical minimum. For the potential astronomer pure mathematics is a 'must', and physics is a desirable second subject. Applied mathematics or chemistry would be acceptable for the third, with preference for the former. Degree courses in astronomy are offered at London (University College), Glasgow and St. Andrews, and courses forming part of a degree at Birmingham, Cambridge, Edinburgh, London and Manchester, but, as explained before, a qualification in astronomy is not essential – mathematics and physics are suitable. Having reached the university and obtained a good degree, say first-class honours or an upper second, the candidate then applies for a post-graduate studentship in a Department of Astronomy. Here he does supervised research leading, it is to be hoped, to a higher degree; financial grants are available for this as well as for the first-degree course. He is then ready to look for a permanent appointment. It is possible but unusual to get one without the post-graduate years.

At the Royal Observatories, and at other Government establishments such as the Radio and Radar Research Stations, the staff belong to the scientific Civil Service. Temporary appointments may be made 'on the spot', but permanent jobs are in the hands of the Civil Service Commission. Entrance to the top grade, Scientific Officer, is similar to that for a university observatory, a good honours degree in mathematics, physics or astronomy. There

are, however, two other grades for people of scientific ability who, for one reason or another, do not hold this qualification but are otherwise considered suitable. For Experimental Officer the minimum qualification is the Intermediate B.Sc., or G.C.E. in five subjects including two science (or maths) 'A'. The minimum age at entry is 18, and if over 22 the candidate will be expected to have an ordinary (pass) degree. There are a few appointments for holders of the Higher National Certificate. The lowest grade, Scientific Assistant, can be entered, in a temporary capacity in the first instance, at 16 with a G.C.E. in four subjects at 'O' level, including English and either mathematics or a science. For radio astronomy a good degree in physics or electrical engineering is the usual requirement, though here there are a few posts for technicians holding the Higher National Certificate or Diploma.

Success in a career depends on matching the personality to the job; we have all heard of the 'round peg in a square hole'. If a person's life work is also that which gives the greatest satisfaction, then that person is a happy one (and all the astronomers the writer has met give the impression of being in that fortunate state). The potential astronomer must have a scientific mind, an unbounded interest in astronomy, and unlimited perseverance. For most people a career must also provide a living, and although salary scales are for ever changing, something must be said about them. The following is a rough guide to the situation in 1962. Salaries in the university observatories mostly lie in the range £800 to £1,850. In the Civil Service the scales are: Scientific Assistant, £333, rising by annual increments to £780 (a few senior posts are rather higher); Experimental Officer, £458 to £1,872; Scientific Officer, £1,082 to £2,418; service is pensionable. If the reader thinks that some of these are low compared with industry, remember that satisfaction in the job, a congenial environment, and security not subject to the uncertainties of industry, count for much, and if he or she wants to be, and is suited to be, an astronomer, the salary is a secondary consideration.

Recent Advances in Astronomy

PATRICK MOORE

The year 1962 has been notable for the continued and rapid progress in space research. It is true that no man has yet reached the Moon – at least, not at the time when these words were being written! – but the Russian achievement in putting two astronauts into orbit at the same time brings the lunar voyage considerably nearer. There is, of course, a real danger of placing too much emphasis on the manned flight projects and too little upon the instrumented programmes; successful completion of the journey of the U.S. space-probe Mariner II, launched on August 27 towards the planet Venus, will be much more useful from a scientific point of view than a dozen orbital flights round the Earth by space-men in capsules. However, nobody is likely to doubt that Andrian Nikolayev and Pavel Popovich achieved a memorable triumph. Their reports appear to tally excellently with those of earlier astronauts, both Russian and American; they even reobserved Colonel John Glenn's famous 'fire-flies', which are interesting even if they are due to nothing more significant than paint flaking off the space-ship's hull!

I heard a recording of Nikolayev's voice, coming from space, not long after his ascent. At that time I was on a brief visit to the Tautenberg Observatory in East Germany, not far from Jena – the town famous because it is the headquarters of the optical firm of Carl Zeiss. Had I been able to speak Russian, I have no doubt that I would have been able to understand what Nikolayev was saying.

Tautenberg is a new observatory, and has become operational only in 1962. The chief telescope has a mirror 79 inches in dia-

meter, manufactured at the Zeiss works, and is of unusual design, since it has three optical systems: Schmidt, Cassegrain and Coudé. Changing from one system to another is a comparatively easy process, and can be carried out within a day; indeed, a switch from Cassegrain to Coudé can be completed in less than three hours.

There are obvious advantages in such a design, particularly in view of the tremendous light-grasp; with the Schmidt arrangement, stars down to magnitude 21 can be photographed in an hour. The telescope is in every way most impressive, and has a closed tube; the total weight is 84 tons. Its first task is to undertake a research programme about star-clusters. Tests have been completed, and the Tautenberg Observatory will undoubtedly play an important rôle in astronomical research. It is, of course, the newest of the great observatories, and is one of the largest in Europe; it lies some way from Jena, and seeing conditions are said to be good. Incidentally, there is still no definite news about completion dates for either the Russian 236-inch reflector or the 98-inch which is being prepared for the Royal Greenwich Observatory at Herstmonceux.

Each year brings its quota of new scientific instruments, but, unfortunately, each year also marks the passing of famous figures of the past. Of astronomers who have died in 1962, special mention must be made of A. E. Douglass and Edison Pettit, both of the United States. Both were associated with studies of the planet Mars; Douglass, indeed, worked with Percival Lowell at the Flagstaff Observatory for some years. Pettit is also particularly remembered for his thermocouple measures, made in collaboration with S. B. Nicolson, and for his work on the magnitudes of galaxies. Yet though Douglass and Pettit have left us, they and their work will not be forgotten.

After the general interest aroused by the total solar eclipse of February 1961, when the track extended across Europe, the eclipse of 1962 February 5 passed unnoticed except among professional astronomers. This was hardly surprising, since almost the only suitable observing site was New Guinea – which is rather far afield

for anybody who has only a day or two to spare. Nevertheless, various expeditions collected on the island, and a research programme was carried through, only mildly hampered by clouds. On this occasion the Japanese astronomers were particularly energetic. At the next total eclipse, which takes place on 1963 July 20, they will not have to leave their homeland, since the track crosses Japan as well as parts of Canada.

Solar activity decreased markedly during 1962, and a few spotless days were reported for the first time in years. This was, of course, expected; the tremendous maximum of 1957–8, the time of the International Geophysical Year, has long since passed, and activity is dying down toward minimum. Until 1967 or so we may now expect the Sun to be relatively 'quiet', though it is never wise to make hard and fast predictions when dealing with anything so vague as the solar cycle.

The Sun is generally regarded as a typical star. This is true enough, and it is certainly no freak; it is neither a vast, rarefied giant nor a tiny, super-dense White Dwarf. The White Dwarfs, it will be remembered, have been described as 'bankrupt stars', and are certainly at a very late stage in their evolution; the atoms in them are crushed and broken, so that a cupful of White Dwarf material would weigh many tons. The most famous example is the Companion of Sirius, irreverently nicknamed the Pup, but many others are now known. They are certainly very numerous, though their extreme faintness makes it difficult for us to detect them unless they are near at hand on the stellar scale of distances.

In 1962 W. J. Luyten, at the University of Minnesota, announced the discovery of the smallest White Dwarf known. Its official designation is LP 357–186; it lies not very far from the Hyades, and is of below the 18th magnitude. Its comparatively rapid proper motion indicates that it is only about 100 light-years away, but it is very blue in colour – not unlike a B-type star. Luyten considers that it can have a diameter of no more than half that of the Moon (around 1500 miles at most), and that its density is 200,000,000 times that of water. If so it exceeds all other members of the class in density, and must be a most remarkable body.

Two old novæ, T Aurigæ and WZ Sagittæ, have also been in the news during the past year. T Aurigæ was discovered in 1891 by an amateur astronomer, Dr Anderson, and attained the 4th magnitude before fading away. For many years now its magnitude has been about 15, so that it has become rather a difficult telescopic object from the amateur viewpoint. M. F. Walker, at the Lick Observatory, has recently found that it is an eclipsing system of the Algol type; the period is about 4 hours 54 minutes, and the eclipse is partial, with a duration of 40 minutes. The drop in brightness at minimum is not great, and amounts to only a quarter of a magnitude at most.

The interesting point here is that T Aurigæ is not the first old nova to reveal itself as an eclipsing system. Eight years ago Walker, then at Mount Wilson Observatory, found that DQ Herculis, which flared up to the first magnitude in 1934 and was discovered by the British meteor observer, J. P. M. Prentice, is a similar kind of binary. The third case is of recent detection; it is that of WZ Sagittæ, which has the distinction of having been observed at two nova-like outbursts – one in 1913 and the other in 1946. R. Krzeminski, at Lick, has found the period to be a mere 80 minutes, which is the shortest known. It will be interesting to see whether any other ex-novæ will prove to show similar characteristics. At least these new developments are of the greatest interest and significance to astrophysicists in general.

We must admit that spectacular novæ have been rare in recent years. Since DQ Herculis only two have been at all conspicuous with the naked eye; Nova Lacertæ of 1936, which attained the second magnitude, and Nova Argûs of 1942, which was somewhat brighter but was so far south in the sky that it was barely observable from England. Similarly, there has been a dearth of bright comets; indeed, the present century has been quite remarkably barren in this respect, since there has been no really 'great' comet since 1910, though during Victorian times there seemed to be a regular supply.

A comet is by no means so important as it may look. It is a very junior member of the Solar System, and even a really large comet

many thousands of miles in diameter is of negligible mass. For instance, the Great Comet of 1843 was larger than the Sun, but its mass was less than that of a normal asteroid. Yet the sight of one of these celestial visitors spreading its tail across the sky must be wonderful indeed. I cannot speak from personal experience, but I have had many eye-witness accounts; indeed, I remember meeting a man who distinctly remembered the beautiful Donati's Comet of 1858, reputed to be one of the loveliest in history.

For a time in 1962 it seemed that we were at last to be favoured with something spectacular. On February 4 Tsutomu Seki, at Kochi in Japan, and R. D. Lines at Phoenix, Arizona, independently discovered the comet which was designated 1962c. It was then of the 9th magnitude, and not far from the bright star Zeta Argûs. It soon developed a tail, and was expected to become really brilliant – perhaps considerably brighter than Venus – during the early part of April.

In fact Comet Seki-Lines did reach a bright magnitude, but it was not well placed for observation when it should have been at its best; it was much too close to the Sun in the sky, and by the time it moved away it had faded. The fading was, indeed, extremely rapid. From England it failed to come up to expectations; I saw it from the clear skies of California, but it was certainly no more striking than the two comets of 1957 (Arend-Roland and Mrkos), which, though prominent naked-eye objects, were very insignificant compared with the great comets of the past. So we must continue waiting; by the law of averages we are surely due for a brilliant visitor even before our old friend Halley's Comet comes back again in 1986.

Of the planets, Mars was badly placed throughout most of 1962; even the opposition of early 1963 will not be favourable, since the planet will not approach us to within 60,000,000 miles. However, both Jupiter and Saturn showed features of exceptional interest, and amateur astronomers were kept busy in studying them.

Jupiter, the giant of the Solar System, is always ready to spring surprises on us; its surface is always changing, and one can never

tell just what will happen next. Ordinarily there are at least two prominent belts, one to either side of the planet's equator, and recently the South Temperate Belt has been prominent as well. For a long time, however, the darkest, broadest and most conspicuous of the belts has been the North Equatorial. This was so even in 1959, when the whole of the equatorial region showed a peculiar and quite abnormal yellow-orange hue which had vanished by 1960 and was again absent in 1961.

When Jupiter became available for observation after conjunction in 1962, a remarkable change was seen. The well-defined equatorial belts had vanished, to be replaced by a very broad yellowish band which covered the entire region; it seemed as though the equatorial belts had merged. Curious white patches were seen in the band from time to time. It was all most interesting, and quite new in the experience of most observers of the planet. Moreover, the famous Great Red Spot was more prominent, and more highly-coloured, than for some time past. The Spot was very conspicuous for some years following 1878, and can be traced on drawings made as long ago as 1631, so that – unlike the other spots on Jupiter – it must be regarded as at least semi-permanent even though it temporarily disappears now and then.

We know a good deal about the way in which Jupiter behaves, but it cannot be said that we have any real idea about the basic cause of the surface variations. It is quite definite, of course, that Jupiter is intensely cold, and is not built on the lines of a 'minor sun' as used to be believed; there is a fundamental difference between a planet and a star, and there is certainly nothing stellar about Jupiter. Neither can the Red Spot and other features be fixed to a solid surface, since they drift about within certain limits – and even the latitudes of the main belts are not entirely constant. Meanwhile, it would be wrong to suppose that the present strange aspect is either fundamental or permanent. No doubt the situation will return to normal before long, perhaps by the apparition of 1963, but it is understandable that planetary observers are paying particular attention to Jupiter.

Saturn, the outermost of the planets known in ancient times, is

both smaller and more remote than Jupiter, so that it does not make nearly so brave a show in the sky. During 1962 the ring-system was still well displayed, but it is probably true to say that the main interest was centred on the globe. Belts are much less prominent than those of Jupiter, and spots are very rare; the last really conspicuous example was discovered as long ago as 1933 by W. T. Hay, though lesser spots have been seen since. On 1962 July 7, I observed a white spot in the equatorial zone. It may well have been seen earlier; in any case it was confirmed later in July by both British and United States observers, though it never attained the prominence of Hay's spot of 1933.

Both Jupiter and Saturn have short rotation periods (9¾ hours for Jupiter, 10¼ for Saturn) but do not spin as solid bodies would do; the rotation period is appreciably shorter for the equator than for higher latitudes. With Jupiter there is considerable information to hand, but the situation with regard to Saturn is less satisfactory, mainly because of the relative paucity of surface markings. It was hoped that the 1962 spot would prove useful in determining the rotation period at its own particular latitude, but it also failed to live up to expectations.

Most astronomical work consists of routine observation, but it is obvious enough that even an 'ordinary' year such as 1962 is full of interest. The skies are always changing, and they can never be dull. And so we enter 1963, wondering, as ever, what is in store for us. Who knows? – before the year reaches its end we may have seen the outbreak of a brilliant supernova, or watched in awe as a glorious comet stretches its tail across the heavens. Time will tell.

Some Recommended Books

General:

Larousse Encyclopedia of Astronomy, by L. Rudaux and G. de Vaucouleurs. (Batchworth, 1959; 63*s.*)
Not an encyclopedia, but a detailed account of astronomy for beginners; 500 pages, and more than 800 diagrams and plates. Value for money.

Elementary Astronomy, by Otto Struve. (Oxford University Press, 1959; 55*s.*) A lavishly illustrated and well-produced book for the reader who does not mind a bit of mathematics.

Astronomy, by Robert H. Baker. (van Nostrand, 1959; $6.95.) A standard textbook, which has now reached its 7th edition.

Astronomy, by T. G. Mehlin. (Chapman & Hall, 1959; 64*s.*) A college textbook with some new ideas.

Introduction to Astronomy, by Cecilia Payne-Gaposchkin. (Eyre & Spottiswoode, 1956; 50*s.*) Excellent general account of astronomy.

Astronomy for Entertainment, by Y. Perelman. (Central Books, 1958; 7*s.* 6*d.*) An unusual elementary account of some aspects of astronomy, translated from the Russian.

Atlas of the Universe, by B. Ernst and T. E. de Vries. (Nelson, 1961; 42*s.*) A detailed and profusely illustrated encyclopaedia of astronomy.

Planets, Stars and Galaxies, by Stuart J. Inglis. (John Wiley, 1960.) An American college textbook, written for the man with little scientific knowledge. Beautifully produced, with many unusual features.

The Fascinating World of Astronomy, by R. S. Richardson. (Faber & Faber, 1962.) A popular book in 'question and answer' form, written by an American astronomer who is as famous for his general books as for his own very considerable contributions to the science.

Measuring the Universe, by Henry Brinton. (Methuen: Outline series, 1962; 9*s.* 6*d.*) A logical, concise account.

Lectures and Essays:

The Nature of the Universe, by F. Hoyle. (Blackwells, 1960; 8*s.* 6*d.*) A second and revised edition of the controversial broadcast talks of 1950.

Radio Astronomy:

Radio Astronomy, by F. Graham Smith. (Penguin, 1960; 7*s.* 6*d.*) An excellent account by one of the Cambridge team.

Radio Studies of the Universe, by R. D. Davies and H. P. Palmer. (Routledge & Kegan Paul, 1959; 25*s.*) Two members of the Jodrell Bank team explain their work.

The Solar System:

The Planet Earth, Ed. D. R. Bates. (Pergamon Press, 1957; 35*s.*) A comprehensive account of geophysics and other earth-sciences by a number of authorities.

The Planet Jupiter, by B. M. Peek. (Faber & Faber, 1958; 42*s.*) The only detailed account – and an excellent one – of this great planet.

Our Sun, by D. H. Menzel. (Harvard Books, Blakiston, 1959; $7.50.) Second edition of a well-known book.

The Face of the Sun, by H. W. Newton. (Penguin, 1958; 3*s.* 6*d.*) Full of information.

The Sun and its Influence, by M. A. Ellison. (Routledge & Kegan Paul, 1959; 25*s.*) Second edition of a very useful book.

The Sun, by A. Severny. (Lawrence & Wishart, 1959; 5*s*.) Translation of a work by a Russian astronomer.

Structure of the Moon's Surface, by G. Fielder. (Pergamon Press, 1961; 50*s*.) A detailed account of lunar science, unreservedly recommended to all those who are interested in the Moon.

Surface of the Moon, by V. A. Firsoff. (Hutchinson, 1961; 21*s*.) The application of geological principles to lunar study.

The Sun's Family, by James Muirden. (Weidenfeld & Nicolson, 1962; 9*s*. 6*d*.) An account of the Solar System, written specifically for readers of school age, but also suitable for adult beginners in astronomy.

The Planet Saturn, by A. F. O'D. Alexander. (Faber & Faber, 1962; 63*s*.) A comprehensive account of Saturn – the first book dealing with this planet to be published for nearly a century. It is indispensable to any student of Saturn, and must remain the standard work.

The System of Minor Planets, by Günter D. Roth. (Faber & Faber, 1962.) Translated from the German by A. L. Helm. The only recent book to deal exclusively with the asteroids.

Space Research:

Cosmic Rays, by G. Zhdanov. (Lawrence & Wishart, 1959; 4*s*. 6*d*.) A paper-back translation of a Russian text.

Satellites and Scientific Research, by D. King-Hele. (Routledge & Kegan Paul, 1962; 25*s*.) One of the best accounts so far of the behaviour and uses of artificial satellites.

Space Laboratories, by G. Zhdanov and I. Tindo. (Foreign Languages Publishing House, Moscow; in English, distributed by Central Books; 1962, 6*s*.) A useful account of the research carried out by satellites and space probes.

Artificial Satellites, by G. V. E. Thompson. (Weidenfeld & Nicolson, 1962; 9*s*. 6*d*.) A popular description of the present satellite programme.

Space Research by Rocket and Satellite, by R. L. F. Boyd. (Arrow Science, 1960; paper 5*s*., library edition 10*s*. 6*d*.) A snappy account of the problems of space research, and how they are solved by instrumented rockets.

Miscellaneous

Changing Views of the Universe, by Colin A. Ronan. (Eyre & Spottiswoode, 1960; 15*s*.) A study of the historical background.

Astronomical Photography, by G. de Vaucouleurs. (Faber & Faber, 1961; 25*s*.) An historical account of the development of astronomical photography, from its earliest days up to the present time.

Physics of Interstellar Space, by S. Pikelner. (Foreign Languages Publishing House, Moscow, 1962; in English, 6*s*.) Semi-technical and highly informative.

A History of Astronomy, by A. Pannekoek. (George Allen & Unwin, 1960; 65*s*.) A translation of a very detailed history of the influence of astronomy on human affairs, written by an authority on the subject; the emphasis is on astronomy, not astronomers.

Life in the Universe, by Francis L. Jackson and Patrick Moore. (Routledge & Kegan Paul, 1962; 18*s*.) A discussion of the problem written jointly by a research bacteriologist and an astronomer.

Astronomical Societies

The advantages of joining an astronomical society are obvious, and this is a step which should be taken by any amateur who is even moderately interested in the subject. The leading society in Britain is of course the Royal Astronomical Society (Burlington House, Piccadilly, London, W.1) which is a professional organization, though there are many Fellows who are amateurs. The leading amateur society is the British Astronomical Association: secretarial address 303 Bath Road, Hounslow West, Middlesex. Meetings are held on the last Wednesday of each month (except July, August and September) at Burlington House, at 5 p.m. The annual subscription is 45*s.*; for a member 25 years of age or less on his last birthday preceding 1 August, the subscription is 30*s.* Special sections are devoted to the Sun, Moon, Mercury and Venus, Mars, Jupiter, Saturn, comets, meteors, variable stars, and aurorae and the Zodiacal Light; there is also a Historical Section, and a section dealing with instruments and observing methods. The B.A.A., founded in 1890, has a distinguished observing record. Publications include a regular *Journal* and annual *Handbook*.

For young enthusiasts there is the Junior Astronomical Society (secretarial address, 44 Cedar Way, Basingstoke, Hampshire) which caters mainly, though not exclusively, for those of school age. Meetings in London are held quarterly at Caxton Hall, near Victoria. The journal, *Hermes*, is issued quarterly. The annual subscription is 10*s.* There are various branches which organize their own programmes: at Croydon (J. H. Lytheer, 1 Temple Avenue, Shirley, Croydon, Surrey); Leeds (D. Fry, 5 Belle Vue Terrace, Belle Vue Road, Leeds 3); Golders Green (Miss L. Morrison, 49 Booth Road, Colindale, London, N.W.9); and Eastbourne (C. Oliver, 33 Commercial Road, Eastbourne, Sussex).

Other branches are in the process of formation. Inquiries should in the first instance be sent to the Society's Secretary, E. W. Turner.

Many towns have their own local astronomical societies. Among these are:

Name	*Secretarial Address*	*Member-ship*	*Annual Subscription*	*Meetings*	*Remarks*
Birmingham Astronomy Group	17 Hannafore Road, Edgbaston, Birmingham 16 (W. E. Marsh)	120	10*s* (5*s* for those under 21)	Monthly, Oct.–May at Midland Institute, Paradise Street, Birmingham	1
Bristol Astronomical Society	12 Lambley Road, Bristol 5 (S. J. Williams)	60	1 guinea (10*s* 6*d* for those under 16)	Monthly, Sept.–May, at Royal Fort, University of Bristol	
Chester Society of Natural Science: Dept. of Astronomy	15 Sheldon Avenue, Chester (Miss N. Thomas)	24	10*s* (6*s* for those under 21)	Grosvenor Museum, Grosvenor Street, Chester	2
Chesterfield Astronomical Society	10 George Street, Brimington, *Chesterfield*	80	15*s*	The Barnett Observatory	3
Crewe Astronomical Society	465 Crewe Road, Wistaston, Crewe, Coventry	60	12*s* 6*d*	Crewe County Grammar School, Ruskin Road, Crewe	
Cumberland and Westmorland Astronomical Society	55 North View, Aspatria, Cumberland, (W. L. Rae)				
Astronomical Society of Edinburgh	126 West Savile Terrace, Edinburgh 9	130	20*s*	Calton Hill Observatory	4
Fellowship of Junior Astronomers, Edinburgh	58 Ogilvie Terrace, Edinburgh 11	30	7*s* 6*d*	Calton Hill Observatory	5
Leeds Astronomical Society	The University, Leeds	120	10*s*	Leeds University, 2nd Wednesday of each month, October–March	
Leicester Astronomical Society	49 Bringhurst Road, Leicester (C. Shuttlewood)	60	1 guinea (10*s* for those aged 16–18; 5*s* for those under 16)	Leicester Museum and Art Gallery	6
Lincoln Astronomical Society	Oak Crescent, Cherry Willingham, Lincoln (P. Hammerton)	80	10*s* senior 5*s* junior	Lincoln Y.M.C.A.	7
Liverpool Astronomical Society	135 St Michael's Road, Great Crosby, Liverpool 23 (J. E. Abrahams)	200	12*s* 6*d* (4*s* for those under 21)	Royal Institution, Colquitt Street, Liverpool	8
Manchester University Astronomical Society	Dept. of Astronomy, The University, Manchester 13	85	3*s*	The University	9

Name	*Secretarial Address*	*Membership*	*Annual Subscription*	*Meetings*	*Remarks*
Manchester Astronomical Society	Craigside, facing Craig Avenue, Summerseat, Bury	150	£1 (seniors) 10*s* (juniors)	Godlee Observatory Manchester College of Technology, Sackville Street, Manchester, 1	10
Newcastle-on-Tyne Astronomical Society	30 Kew Gardens, Whitley Bay, Northumberland	64	15*s* (students 7*s* 6*d*)	King's College, Newcastle	
Nottingham Astronomical Society	61 Abbey Road, Beeston, Notts (Miss M. Mott)	30	1 guinea	Nottingham Mechanics Institute; first Thursday in each month	11
Norwich Astronomical Society	68 Clarendon Road, Norwich (W. E. Bennett)	60	15*s* (7*s* 6*d* for those under 17)	Assembly House, Norwich, and the Observatory	12
Swansea Astronomical Society	77 Graiglwyd Road, Cockett, Swansea (R. E. Roberts)	25	1 guinea	Royal Institution of South Wales, Swansea	13
Torbay Astronomical Society	Bluehaze, Clennon Park, Paignton, Devon (Mrs A. Longman)	30	15*s*	R.A.F. Training Centre Newton Abbot, Devon; third Thursday of each month	
Warwickshire Astronomical Society	9 Tallants Road, Bell Green, Coventry (A. Hancocks)	25	£4 (£2 for those age 17–21)	20 Humber Road, Stoke, Coventry	14
York Astronomical Society	27 Garden Flat Lane, Dunnington, York	30	£1 (students 5*s*)	York Educational Settlement	15
Preston and District Astronomical Society	Ormonde, 51 Bispham Road, Carleton, Poulton-le-Fylde, Lancs (C. Lynch)	30	15*s* (juniors 5*s*)	Chamber of Commerce, 49a Fishergate, Preston 3rd Monday of each month, Sept.–May inclusive, 19.30 h.	16
Hull and East Riding Astronomical Society	Rosedene. Flinton, Sproatley, nr Hull	40	10*s* (School pupils 5*s*)	Kingston High School, Hull	17
Wolverhampton Astronomical Society	61 Bushbury Lane, Wolverhampton (M. Astley)	61	15*s* (5*s* to ladies and those under 18)	Committee Room, 38 Tettenhall Road, Wolverhampton 7.40 pm, alternate Mondays, Sept.–April	18

Remarks

1. The Group has a 12 in. reflector in an observatory at Birmingham, and a 21 in. is under construction. General meetings are held once a month from October to May, with lectures and film shows. The Construction Section meets weekly throughout the year. The Group runs a lending library, an observing section, and a junior section.

2. From January to May a course of lectures is held in conjunction with the Liverpool University extra-mural department, on subjects allied to astronomy. Open to non-members of the Society. Fee 7*s.* 6*d.*

3. The Observatory has an 18 in. Newtonian reflector and also a lecture room.

4. Facilities are available to members at the Observatory, Calton Hill. Small telescopes are also loaned to members of the Observing Sections. Members meet on Fridays throughout the year at the Observatory. Library, and a collection of lantern slides. Monthly star maps and astronomy notes are issued to all members.

5. There are observing nights at the Observatory, Calton Hill. Monthly notes are issued to members. Some small telescopes are loaned to members. Training is given in observing techniques. There is a small library.

6. The Observatory, with a 15 in. reflector, will be completed in 1962.

7. An observatory and lecture room are now being built.

8. The Society, founded in 1881, has a strong junior section, a radio physics section, a library and a collection of lantern slides. Telescopes are available for borrowing by members, and the Society's 5 in. Cooke equatorial is available to members at a weekly meeting held at the Society's Observatory, Central Technical College, Byrom Street, Liverpool.

9. The Society has the use of the Godlee Observatory, operated by the Manchester Astronomical Society. The Society also has facilities for producing telescope objectives, etc.

10. The Society's 12 in. and 8 in. reflectors are available two nights per week at least. Winter session lectures are held in the Reynolds Hall of the College.

11. The 8·5 in. Society reflector is kept by the Director of Observing, A. W. Lane Hall.

12. The Society has its own observatory, with a 10 in. reflector, and adjoining club-room, off Newmarket Road, Norwich. This is available to members at any time by arrangement. Regular evenings are Tuesdays, Wednesdays, and Saturdays.

13. The Swansea Observatory has a 9 in. Newtonian reflector, and photographic equipment.

14. Workshops contain grinding and polishing facilities. The Library and Club Room, available seven days a week, are available to all members. There is a monthly magazine, *Cosmos*.

15. Meetings are held at 7.30 on the second Thursday of each month.

16. The observational work of the Society is carried out at the Jeremiah Horrocks Observatory, Moor Park, Preston, on Monday evenings.

17. The observatory at Kingston High School, Hull – equipped with a 4-inch refractor – is available for use by arrangement. Meetings are held in the second Friday of each month from October to April inclusive.

18. Library facilities are available.

This list of societies may not be quite complete. The secretaries of any societies not included are invited to send details to Patrick Moore, c/o Eyre & Spottiswoode (Publishers) Ltd, 22 Henrietta Street, London WC2, for inclusion in the 1964 *Yearbook*.

Glossary of Astronomical Terms

aberration—(1) the distortion of an image in an imperfect optical system; (2) the apparent displacement of a star from its true position owing to the finite velocity of light. It includes (*a*) the effect of light-time, the object being seen where it was when light left it; this effect is ignored in dealing with stars, since the light-time is not known; (*b*) the effect of the Earth's motion, which, combined with the velocity of light, causes an apparent displacement of the object. This effect is called *stellar aberration*, and the combination of the two effects is *planetary aberration*.

absorption lines—dark lines in a continuous spectrum caused by absorption of light of certain wave-lengths by a layer of gas (e.g., an atmosphere) cooler than the source of light.

albedo—('whiteness')—the ratio of the amount of sunlight reflected from a planet or satellite to the amount received. The Moon reflects only 7 per cent of the sunlight falling on it; its albedo is therefore 0.07.

altitude—the angular distance of a body above the true horizon; the nature of the visible horizon will affect the apparent altitude.

angstrom unit—the unit of wave-length in measurements of light, X-rays, etc. Symbol A; it is one hundred-millionth part of a centimetre, or a ten-thousandth part of a micron. The whole of visible light is contained in the range from 3,900A (violet) to 7,500 A (red).

aphelion—that point in an (elliptical) orbit of a planet or comet which is farthest from the Sun.

apogee—that point in the orbit of the Moon, or of an artificial satellite, which is farthest from the centre of the Earth.

apparent place—the observed position of a star or planet, as distinct from the mean place.

apparent solar time—time measured by the hour angle of the true Sun; the time measured by a sundial. The difference apparent time *minus* mean time is the *equation of time*, and this may amount to more than 16 minutes in November.

appulse—a very close conjunction of two planets, or of a planet and a star.

apse line, or *line of apsides*—the line in an orbit which joins the nearest and farthest points from the central body; in an unperturbed ellipse it corresponds to the major axis.

asteroids—see *minor planets*.

Astronomical Ephemeris—the modern name (since 1960) of the British *Nautical Almanac*, which was first published in 1767; it is identical in content with the *American Ephemeris*.

astronomical unit—the mean distance of the Earth from the Sun; the semi-major axis of the Earth's orbit. May be taken as 93 million miles.

astrophysics—the branch of astronomy which uses the laws of physics to study the constitution and evolution of the stars.

azimuth—the angular bearing of an object measured round the horizon from north or south points. In astronomy it is now usual to measure the azimuth from the north round through east, south and west, from 0° to 360°.

binary—a double star in which the two components are physically connected, revolving about their common centre of mass under the influence of the mutual gravitational forces. Probably one star in every two or three is a binary.

celestial sphere—an imaginary sphere of infinite radius, centred at the observer, on which the stars and planets appear to be fixed.

Their positions may then be referred to fixed great circles (such as the equator or ecliptic) on the sphere.

cepheid—a variable star characterized by a rapid rise to maximum brightness, followed by a slower and less regular decline; named after the typical star Delta Cephei. The periods range from 1 to 45 days, and the period is in all cases proportional to the absolute brightness, from which distances can be measured.

chromosphere—the lower layer of the Sun's atmosphere, red in colour, and consisting mainly of hydrogen; it extends for some thousands of miles, while prominences rise from it to much greater distances.

circumpolar stars—stars which do not rise or set, but merely circle the pole; all stars whose declinations are greater than the colatitude of the observer are circumpolar.

cluster variables—short period variable stars first detected in globular clusters, and having periods less than one day.

clusters—groups of stars having a common motion through space. The main groups are (1) open clusters within the Galaxy containing at most a few hundred stars with dust and gas clouds; (2) globular clusters of a symmetrical shape, containing many thousands of stars including short-period variables and Population II stars. They are distributed uniformly at great distances round the centre of the Galaxy.

colatitude—the complement of the latitude; 90° minus the latitude. The meridian altitude of the equator at any place is equal to the colatitude.

colour index—the difference between the photographic and visual magnitudes of a star; from this value the effective temperature may be deduced.

comes—the fainter component of a double star.

conjunction—the nearest apparent approach of two celestial objects, when one appears to pass the other; usually considered to occur when they have the same longitude.

Inferior conjunction of Mercury and Venus occurs when the planet is between the Sun and the Earth.
Superior conjunction of any planet occurs when it is on the farther side of its orbit, the Sun lying between planet and Earth.

continuous creation—the theory that matter is being continuously created throughout the universe, to replace losses caused by the recession of the galaxies. This is the *steady-state* theory, and it implies that the universe had no beginning and will have no end; creation is confined to individual systems.

corona (*solar*)—a pearly-white halo of light surrounding the Sun; this is the outer layer of the Sun's atmosphere, and can be traced to great distances from the Sun, joining up with the zodiacal light.

cosmic radiation—highly penetrating radiation which reaches the Earth from outer space; it consists of electrically charged particles of high energy.

cosmogony—the science which deals with the origin of the universe, or of our Galaxy or the solar system.

cosmology—the study of the universe as a whole, its nature in space and time, and the relations between its various parts.

cusps—the horns of the moon or of an inferior planet when in the crescent phase.

D-layer—the lowest ionized layer in the Earth's atmosphere; it is about 50–60 miles above the Earth, and disappears almost completely at night.

day—the period of the Earth's rotation. It may be measured with respect to the stars (*sidereal day*), the true sun (*apparent solar day*) or the mean sun (*mean solar day*). See *apparent solar time, Greenwich Mean Time, mean solar time, sidereal day.*

declination—the angular distance of a celestial object north (+) or south (−) of the celestial equator.

dew cap—an open tube fitted to a refractor, extending the telescope tube beyond the objective; it prevents condensation on the front surface of the lens.

diffraction rings—the image of a star in a telescope is not a point, but has a definite size; this 'spurious disc' is surrounded by a number of diffraction rings. These are caused by the spreading of light (which is a wave-motion) round the edges of an obstacle —in this case, the aperture of the telescope—to give alternate light and dark bands called diffraction fringes. If the aperture of the telescope is increased, the spurious disc becomes smaller, and the diffraction rings less conspicuous.

Doppler effect—the apparent change of wave-length in any form of wave-motion (sound, light, radio, etc.) caused by the motion of the observer or of the source, or both. The change is proportional to the velocity.

double stars—two stars which appear close together in the sky, either because they are physically connected (see *binary*) or because they chance to be almost in line, though at different distances (optical double).

dwarf stars—the stars of the *main sequence*; the giant stars are more luminous, and the white dwarfs less luminous, than the stars of the main sequence.

eclipse—an eclipse of the Moon (or any other satellite) occurs when it passes into the shadow of the planet; such an eclipse may be *penumbral* if the satellite does not enter the umbra of the shadow, or *partial* or *total*. An eclipse of the Sun occurs when the Moon passes between the observer and the Sun; in this case the eclipse may be *partial*, *annular* (ring-like, if the Moon does not entirely cover the Sun's surface) or *total*. An eclipse of the Sun can only occur at New Moon, and an eclipse of the Moon only at Full Moon.

ecliptic—the great circle on the celestial sphere which marks the apparent path of the Sun. It is the projection of the Earth's orbit on the celestial sphere.

elongation—the apparent angular distance of a planet from the Sun, or of a satellite from the parent planet, etc.

emission lines—bright lines in a spectrum due to the emission of light from a glowing gas at low pressure.

ephemeris—a table of positions of the Sun, Moon, planets, comets, etc., for given dates at regular intervals.

epoch—a date chosen for reference purposes in quoting astronomical data which vary with time, e.g., the position of the equinox, or the elements of an orbit, are always quoted for a certain epoch.

equator—the celestial equator is the great circle on the celestial sphere which is the projection of the terrestial equator.

equatorial—a telescope arranged to rotate about an axis parallel to the Earth's axis, so that as it turns it will keep a star constantly in the field of view as it moves from east to west across the sky.

equinox—one of the points of intersection of the equator and ecliptic; also the times at which the Sun passes through these points, the vernal equinox occurring on 20 or 21 March, the autumnal equinox on 23 September. The vernal equinox or First Point of Aries is the origin from which right ascension and longitude are measured.

escape velocity—the least velocity which an object must acquire, at a given distance from a centre of attraction (e.g., Sun or planet), in order to escape from the gravitational field of the attracting body in a parabolic orbit. This parabolic velocity depends on the distance, and is 1·414 times the velocity in a circular orbit at that distance.

evening star—(1) the planets Mercury or Venus when seen in the western sky at sunset; (2) also used more loosely to describe any planet which (after opposition) transits before midnight.

expansion of the universe—the recession of the extra-galactic nebulae, at rates which are proportional to their distances, is taken as evidence that the universe is continuously expanding. See *red shift*, *Hubble's constant*.

extra-galactic nebulae—the nebulae that lie outside our Galaxy; they are themselves galaxies, and tend to form clusters.

First Point of Aries—see *equinox*.

flares (*solar*)—brief but very bright outbursts of hydrogen, seen on the Sun, usually in the neighbourhood of sunspots; often cause radio fade-outs and magnetic disturbances on Earth.

flare stars—stars whose spectra show outbursts of light of a similar nature to solar flares, but on a much greater scale.

free fall—the normal state of motion in an orbit in space under the gravitational attraction of a central body. In free fall, the vehicle is not driven, and everything within it is in a state of zero gravity.

frequency—the number of waves passing a given point every second. The product of frequency and wave length gives the velocity of the waves.

galaxies—the name now used for the extra-galactic nebulae; it is estimated that 10,000 million galaxies are observable.

Galaxy—(1) the Milky Way; (2) the entire system of gas, dust and stars, of which the Sun is one; it is now known to have a spiral structure.

gauss—the unit in which the intensity of a magnetic field is measured. The Earth's magnetic field varies over the surface from about 0·3 to 0·6 gauss.

gegenschein—a faint glow in the sky sometime seen on the ecliptic opposite the Sun. It appears to be connected with the zodiacal light, and is sometimes called the counterglow.

Geiger counter—a gas-filled tube which permits an electric charge to pass through it when the gas is ionized; used for counting the number of charged particles that enter it.

geocentric—having the centre of the Earth as origin or as viewpoint.

giant stars—stars which are more luminous (and therefore have a greater surface and size) than the main sequence stars of the same spectral type.

great circle—a circle on the celestial sphere which divides the sphere into two equal hemispheres, e.g., the horizon, the

equator, the ecliptic. The shortest distance between two points on the celestial sphere is an arc of a great circle.

Greenwich Mean Time (G.M.T.)—mean solar time, measured from the meridian of Greenwich and reckoned through 24 hours from Greenwich midnight; it is identical with Universal Time.

Hα (hydrogen alpha)—one of the lines of the hydrogen spectrum; it is prominent in the spectrum of the Sun (at 6563 A) and gives the red colour to the chromosphere and prominences.

harvest moon—in the northern hemisphere the Full Moon which occurs nearest to the autumnal equinox, when the Moon rises on successive nights at about the same time. The same phenomenon occurs in March–April in the southern hemisphere.

heliocentric—having the Sun as origin; viewed from the centre of the Sun.

horizon—the great circle on the celestial sphere which is everywhere 90° from the zenith; the observed horizon will differ from this because of obstructions or the height of the observer.

hour angle—the angular distance of a celestial body from the meridian, measured along the equator westwards in hours minutes and seconds; it is found by subtracting the right ascension of the body from the local sidereal time.

Hubble's constant—the factor of proportionality in Hubble's Law connecting the velocity of recession of the galaxies with their distance. Recent work suggests a value of 55 km/sec per million light-years, and this leads to a figure of about 6,000 million years since the recession began, i.e., when the galaxies were almost in contact. See *expansion of the universe*.

Hunter's Moon—the Full Moon following the harvest moon, at which time conditions are often very similar.

hydrogen I and II—the hydrogen of interstellar space is either neutral atomic hydrogen (hydrogen I), or ionized hydrogen (hydrogen II). Hydrogen I is observable only by means of the

21 centimetre radio line; hydrogen II is found in the neighbourhood of very hot stars, and is readily photographed.

inferior planets—Mercury and Venus, which are inferior in the sense of revolving in orbits smaller than the Earth's.

inner planets—the planets Mercury to Mars; a loose term used to distinguish them from the outer planets, which lie at much greater distances from the Sun.

interferometer—an instrument for making very small measurements by utilizing interference fringes. Two rays of light travelling along different paths from the same source may reinforce or cancel each other, so producing alternate light and dark bands, the distance between which is a measure of the difference in the two paths of the light rays. The optical interferometer has been used for measuring the diameters of some supergiant stars; similar principles are used in the interferometers used in radio astronomy.

interplanetary matter—a term which may be used to include comets, meteoric dust, cosmic rays, dust, electrons, etc., and which emphasizes the fact that space is not empty.

interstellar hydrogen—the commonest element in the universe—see hydrogen I and II.

ionization—the production of electrically charged particles from a neutral atom or molecule. In astronomy the ions of the metals, and of hydrogen and other gases are of the most frequent reference; these are ionized by the loss of electrons, producing positively charged ions.

ionosphere—the upper region of the Earth's atmosphere, in which the gases are largely ionized. Several layers (F-layer, E-layer, D-layer) are recognized, and these have the property of reflecting radio-waves, so making long-distance short-wave communication possible.

island universes—an old term for the extra-galactic nebulae.

isophotes—lines which connect points of equal light intensity on a

graph or chart; the effect is to produce a kind of contour map which indicates levels of brightness.

kiloparsec—a thousand parsecs; about 3,260 light-years.

latitude—(1) on Earth, the angular distance north or south of the equator; (2) celestial latitude is the angular distance north (+) or south (−) of the ecliptic.

librations—apparent oscillations of the Moon on its axis, due to the inclination of the orbit of the Moon, and to its varying velocity. The term is also used of other forms of oscillation of planets or satellites.

light-time—the time taken by light to travel from a celestial object to the observer. This may vary from a little more than a second in the case of the Moon, to many thousands of millions of years in the case of some of the distant galaxies.

light-year—the distance that light travels in a year at a speed of 186,000 miles a second. It amounts to 5,880,000,000,000 miles or 63,240 astronomical units. The nearest known star (Proxima Centauri) is at a distance of 4·3 light years.

line of sight velocity—see *radial velocity*.

local group—a cluster comprising nearly a score of galaxies, of which our Galaxy is one; the group also includes the Andromeda nebula and the Magellanic clouds.

longitude—(1) on Earth, the angular distance east or west of the meridian of Greenwich; (2) celestial longitude is the angular distance, measured along the ecliptic from 0° to 360°, eastwards from the equinox.

luminosity—the actual output of light of a star, as opposed to the apparent brightness measured on Earth by an observer.

Lyman alpha—the first (longest wavelength) of a series of lines in the ultra-violet spectrum of hydrogen.

Lyot filter—a light filter used in viewing the Sun; it allows the passage of light of a very restricted wave-length band (usually that of Hα) and permits direct observation of the sun's chromosphere.

M = Messier. An abbreviation applied to the number of a nebula in Messier's catalogue.

Magellanic clouds—two large irregular nebulae visible to the naked eye in the southern hemisphere; these are the two nearest galaxies.

magnetic field—the entire space in which magnetic forces can be detected; apart from the Earth's magnetic fields, there are known to be strong magnetic fields associated with sunspots and certain stars, and there is believed to be a magnetic field in interstellar space.

magnetic storms—large scale disturbances in the Earth's magnetic field, associated with solar activity; usually accompanied by displays of aurorae and the disruption of radio and telegraphic communication.

magnitude—the measure of apparent brightness of a star or planet. The naked eye can appreciate stars down to magnitude 6, but the 200-inch telescope can photograph stars a little fainter than magnitude 22. A difference of one magnitude represents a ratio of brightness of 2·512; an increase of 5 magnitudes therefore indicates a hundred-fold decrease in brightness. *Absolute magnitude* is the magnitude a star would have if it were seen from a standard distance of 10 parsecs.

main sequence—if the stars are arranged in order of increasing absolute magnitude, the vast majority of them form a progressive sequence of decreasing temperature, size and brightness; this main sequence is best displayed on a graph of absolute magnitudes against spectral type, colour index or temperature. The Sun belongs to the main sequence.

mass spectrometer—an instrument for determining the masses of positively charged particles (e.g. metal ions) by measuring their displacement in a combined magnetic and electrostatic field.

mean place—the position of a star as given in a star catalogue is a mean place, referred to some particular epoch and equinox. The effects of precession, nutation, aberration and (where

appreciable) of parallax, proper motion and orbital motion have been removed; these can be re-calculated for any future date, and when added to the mean place give the apparent place for that date.

mean solar time—a uniform measure of time defined by the hour angle of the mean sun; see *G.M.T.*

mean sun—an imaginary body which moves round the celestial equator at a uniform speed equal to the average rate of motion of the true Sun round the ecliptic.

meridian—the great circle on the celestial sphere which passes through the poles and the zenith, intersecting the horizon at the north and south points. The term is generally used only of the upper meridian, i.e., that part of the meridian from the south point, up through the zenith to the pole.

meteor—a 'shooting star'; not a star, but a small particle which enters the Earth's atmosphere from outer space, and is destroyed by friction, leaving a luminous streak in the upper atmosphere; height 40 to 90 miles, speed 10 to 40 miles per second. The very bright meteors are called *fireballs*, or (if they explode) *bolides*. Most meteors are sporadic, but certain streams of meteoric dust are known, whose orbits about the Sun are intersected by the Earth each year. The resulting increase in the number of meteors, which will all come from some particular radiant, is known as a *meteor shower*. Meteors are also detected by radar methods and some daylight showers are of great interest.

meteorite—a solid body of iron or stone which falls on the Earth's surface from outer space; meteorites are thought to be of a different nature from the average meteor, and are probably derived from minor planets rather than comets.

Metonic cycle—a period of nineteen years, after which the whole cycle of phases of the Moon repeats on the same days of the year; named after the Greek astronomer Meton (*c.* 432 B.C.).

micrometeorites—fine dust of a meteoric origin, but too fine to be destroyed by friction in the atmosphere.

micron—a unit of length equal to one thousandth of a millimetre.

midnight sun—a popular term for the appearance of the Sun above the horizon all night in high latitudes; the phenomenon is visible at some period of the year from all places within the Arctic or Antarctic circles. The Moon and planets can, of course, display the same phenomenon.

Milky Way—the band of light extending round the sky, which is shown by the telescope to consist of countless faint stars; it represents our view of the Galaxy in which we are immersed.

minor planets—a swarm of small bodies, less than 500 miles in diameter, most of which revolve about the Sun between the orbits of Mars and Jupiter. About 1,600 have well-defined orbits, but their total number probably runs into hundreds of thousands. Also called *asteroids*.

month—the average period of revolution of the Moon about the Earth; it bears no relation to the calendar month. The length of the month depends on the point of reference; the more important are the *sidereal month*, referred to the stars, of 27·32 days, and the *synodical month*, referred to the Sun, and giving 29·53 days between similar phases. Owing to the variations in the Moon's orbit, the actual length of the month may vary considerably.

morning star—Mercury or Venus, when seen in the eastern sky before dawn. Also used as a loose description of any planet which transits after midnight (i.e., before opposition).

Nautical Almanac—the navigational ephemeris, giving astronomical information in a form suitable for use by navigators.

nebulae—originally the term referred to any hazy patch of light among the stars; it is now restricted to the gaseous nebulae (either bright or dark) which are found in or near the Milky Way, and are irregular in outline. The extra-galactic nebulae, more regular in shape, show the spectrum of starlight, and are galaxies (spiral, elliptical, etc.); they are found in all parts of the sky.

neutrons—the neutral particles which, together with protons, form the nuclei of atoms.

node—the points at which the orbit of a planet, comet, satellite, etc., intersects the plane of the ecliptic (or other great circle of reference).

nova—a star which appears suddenly in the sky. Sometimes called 'new' or 'temporary' stars, but the appearance is due to an intense outburst of light from the surface of an unstable star. A score or more appear every year in our Galaxy. See also *supernova*.

nucleus—the massive part of an atom, composed of protons and neutrons. The term is also applied to the denser parts of the head of a comet or other luminous object.

nutation—a nodding of the Earth's axis; a small irregular oscillation of the pole about its mean position, and therefore additional to the slow uniform motion of precession.

obliquity of the ecliptic—the angle between the equator and the ecliptic; may be regarded as the angle at which the Earth's axis is tilted.

occultation—the disappearance of a star (or other body) by the passage in front of it of a nearer body of larger apparent size. The most important occultations are those of stars, planets, and radio sources by the Moon.

opposition—a superior planet is at opposition when its longitude differs from that of the Sun by 180°.

outer planets—a term used for the planets Jupiter to Pluto.

parabolic velocity—see *escape velocity*.

parallax—the apparent change in the position of an object on the celestial sphere caused by a change in position of the observer. *Annual parallax* is the change in position of a star due to the annual motion of the Earth, and is the angle subtended by the radius of the Earth's orbit; generally called simply parallax. *Horizontal parallax* of the Moon or of a planet is the angle subtended at that body by the Earth's equatorial radius.

parsec—the distance at which the (annual) parallax of a star is 1 second of arc. It is a large unit, equal to 206,265 astronomical units, or 3·26 light-years.

penumbra—the outer diffuse region of the shadow of the Moon or of a planet, where some light is still received from the Sun; the term is also applied to the outer regions of a sunspot.

perigee—that point in the orbit of the Moon, or of an artificial satellite, which is nearest to the centre of the Earth.

perihelion—that point in an orbit in the solar system which is nearest to the Sun.

perturbations—disturbances in the regular orbital motion of a planet, comet, etc., caused by the gravitational attraction of other bodies.

phases—the changing shape of the illuminated part of the Moon (or of a planet or satellite) due to the relative positions of Sun, Moon and Earth. The Moon and the inferior planets show all the phases from *new* (when the body is invisible) through *crescent*, *quarter*, *gibbous* to *full*, decreasing through *gibbous*, *quarter* to *crescent* and *new* again. The superior planets and their satellites show only the full and gibbous phases.

photoelectric cell—an electronic device in which the incidence of light causes a change in an electric current.

photoelectric photometry—an important branch of modern photometry in which the photoelectric cell is used to measure stellar magnitudes, etc.

photographic zenith tube (P.Z.T.)—a fixed telescope directed to the zenith, used for photographing stars as they pass overhead for the exact determination of time.

photometry—the measurement of the apparent brightness of a distant source, such as a star, by comparison with that of a source of known intensity.

photomultiplier—a complex form of photoelectric cell, giving enormous amplification of the initial current.

photon—the smallest amount (or 'quantum') of light energy. It

may be thought of as a particle whose mass depends on the frequency, or as a short train of waves.

plage—bright hydrogen or calcium clouds that are observed near sunspots in the Sun's chromosphere; originally called 'bright flocculi'.

planet—a large, cold, solid body, moving in an elliptical orbit about the Sun, and shining solely by reflected sunlight. In addition to the nine major planets, many hundreds of minor planets are regularly observed.

polarization—the process by which light or radio waves are restricted to vibrations in one direction (or plane) only.

pole—the celestial poles are the points on the celestial sphere towards which the axis of the Earth is directed. The word is also used with reference to any great circle; the diameter of the sphere which is perpendicular to the great circle will intersect the sphere at two points called poles.

Populations I and II—a term used by Baade to distinguish two main types of stars. Population I contains the hot blue-white stars found in the arms of spiral galaxies; Population II stars are the older red stars found in the central regions of galaxies and in globular clusters, where dust and gas are absent.

position angle—the direction of one object from another; measured from the north point of the principal object through east from 0° to 360°.

precession—the slow twisting of the Earth's axis in space, the pole describing a circle round the pole of the ecliptic in a period of about 26,000 years. This does not alter the relative positions of the stars, but causes the equinox to move westwards round the ecliptic, so that the positions of the stars with respect to the equator (i.e., the R.A. and dec.) or the horizon change slowly with time.

primary focus—(prime focus)—the focal plane of the objective or main mirror of a telescope; the term indicates that the instrument is used without an eyepiece or any other lens or mirror.

profile, line—a tracing of the intensity of the image of an emission line; measured across the line it reveals the fine structure in detail.

proper motion—the motion of a star at right angles to the line of sight; the actual change of position of the star due to its real motion in space.

proton—the positively charged particle which forms the nucleus of the hydrogen atom. The nuclei of other atoms are composed of protons and neutrons.

pulsating stars—variable stars, both irregular and of the cepheid type. Such stars are believed to expand and contract, and are brightest when contracted. The behaviour is not, however, completely understood.

quadrature—the positions of two celestial bodies when their directions from the observer are at right angles; generally used of the Moon or a planet when at an elongation from the Sun of 90° or 270°.

radial velocity—the velocity of a star towards, or away from, the observer; measured by the Doppler effect in the star's spectrum.

radiant—the point (or small area) from which the tracks of the meteors in a meteor shower appear to originate. This is an effect of perspective (as in the case of railway lines), the paths of all the meteors in the shower being sensibly parallel.

radio astronomy—the study of radio waves received from the Sun, planets, interstellar hydrogen, and more distant galactic sources; also the use of radar methods in studying the Moon, planets, meteors, etc.

radius vector—the line joining any body revolving in an orbit to its centre of attraction, as the line joining a planet to the Sun.

red shift—the extra-galactic nebulae show a displacement of their spectral lines towards the red end of the spectrum. This is interpreted as a Doppler effect, indicating that all these galaxies are receding from us. See *expansion of the universe*.

reflector—a reflecting telescope, in which the initial image is formed by reflection from the upper surface of a spherical or parabolic mirror.

refractor—a refracting telescope, in which the image is formed by refraction through the main lens, called the object glass or objective.

refraction—the bending of a ray of light when it passes from one transparent medium to another.

resolving power—the ability of an optical instrument to show fine detail or to separate the images of very close objects; resolving power depends on the aperture of the instrument.

retrograde motion—(1) the apparent westerly motion of a planet among the stars caused by the easterly motion of the Earth; with a superior planet, opposition occurs about the mid-point of the retrogression. With the inferior planets, retrograde motion occurs at the time of inferior conjunction, and is not so readily observed. (2) True retrograde motion occurs in the orbits of comets and satellites which have inclinations greater than 90°.

revolution—orbital motion about a centre of attraction, as in the revolution of the Earth about the Sun.

right ascension—the angular distance of a body from the equinox, measured eastwards along the celestial equator, and usually expressed in hours, minutes and seconds up to 24 hours.

rotation—the turning of a body about its axis; thus the Earth rotates about its axis, but revolves about the Sun.

Saros—the eclipse cycle of 6,585·3 days (18 years and 10 or 11 days) after which Sun and Moon return to the same relative positions with respect to the Moon's node, and the entire series of eclipses repeat in the same order and under similar conditions. During one Saros there are about 70 eclipses, 41 of the Sun and 29 of the Moon.

Schmidt telescope—a reflector in which the surface of the main mirror is part of a sphere, and the resulting aberrations are

corrected by a thin glass correcting plate placed before the mirror.

semidiurnal arc—the angle (or the time) required by a celestial object to describe its apparent motion across the sky from rising to transit, or from transit to setting.

sidereal day—the interval between two successive transits of the same star; it is equal to $23^h\ 56^m\ 04^s{\cdot}09$ of mean solar time, and the difference from 24 hours causes the stars to rise and set 4 minutes earlier each day.

sidereal period—the period of a planet or comet measured with respect to the stars.

sidereal time—time measured by rotation of the Earth with respect to the stars. The sidereal time at any place is equal to the right ascension of an object on the meridian at that time.

solar motion—the motion of the Sun (with reference to the neighbouring stars) of about 12 miles per second towards the constellation Hercules; the term is also used of the Sun's share in the rotation of the Galaxy, which carries it towards the stars of Cygnus at about 130 miles per second.

Solar System—the Sun, with its family of planets, comets, meteors, satellites, dust and gas, all of which are controlled by the Sun's gravitational attraction and are influenced by its radiation.

solar parallax—the horizontal parallax of the Sun; it amounts to $8''{\cdot}79$, from which is derived the distance of the Earth from the Sun.

solstice—the place (or the time) at which the Sun reaches its greatest declination north (summer solstice) or south (winter solstice).

spectral types—the main types of stellar spectra, arranged in order of decreasing temperatures, are denoted by the letters O-B-A-F-G-K-M-R-N-S, each group being further subdivided by the use of small letters or of figures from 0 to 9. There is thus a progression from the hot blue-white helium stars, through the

hydrogen stars of type A to the stars of type G, like the Sun, in which numerous metallic lines are seen; the stars of later types become cooler and redder, and show absorption bands due to molecules such as titanium oxide and carbon compounds.

spectrograph—an instrument for photographing spectra.

spectroheliograph—an instrument for photographing the Sun in the light of one particular wave-length, giving, for example, the appearance of the hydrogen or calcium clouds of the chromosphere.

spectrohelioscope—an instrument for continuously viewing the Sun in the light of one wave-length.

spectroscopic binaries—binary stars which are so close together as to be invisible in the telescope, but which are so placed that their double spectra can be studied by means of the Doppler effect.

spectrum—the rainbow band of colours produced when white light from a small source is passed through a glass prism is really a series of overlapping images of the source, each different colour corresponding to a definite wave-length. Only an incandescent substance produces this continuous spectrum; a single element in the gaseous state produces a line spectrum, i.e., only certain wave-lengths are present, as coloured lines. The positions of these lines serves to identify the element. See also *emission lines, absorption lines, Doppler effect.*

star—a self-luminous globe of gas of the same general nature as the Sun, although it may differ in size and temperature, etc. There are probably a hundred thousand million stars in our Galaxy.

stationary point—a point in the apparent path of a planet at which it appears to be stationary in longitude (but may still be moving in latitude). Stationary points occur at the beginning and end of the period of retrograde motion, i.e., before and after opposition or inferior conjunction.

steady-state theory—see *continuous creation.*

Sun—a star of spectral type G and absolute magnitude +5. It is a sphere of intensely hot gas, about 864,000 miles in diameter; the surface temperature is about 6,000°C but must rise to many millions of degrees in the interior. The visible surface is the *photosphere*, above which lie the *chromosphere* and the *corona.* The Sun rotates, in the same direction as the planets revolve, in about 25 days.

sunspot—a dark spot appearing on the Sun; the dark centre (the *umbra*) is surrounded by the lighter *penumbra*, but they only appear dark by contrast with the brilliant solar surface. A sunspot may be as much as 100,000 miles or more across.

sunspot cycle—the number of sunspots shows a marked tendency to maximum about every eleven years; there are considerable variations both in the numbers and the period.

supergiant stars—intensely luminous stars of low density and great size; their constitution and evolution appear to be different from that of ordinary stars.

superior planets—the planets from Mars to Pluto, which revolve in orbits larger than that of the Earth.

supernova—an exceptionally brilliant nova, rare in our Galaxy, but so brilliant that about 50 have been observed in other galaxies. The Crab nebula is the remains of a supernova explosion.

synchrotron—a machine for accelerating charged particles in a combined electrostatic and magnetic field. At very high energies, an electron beam produced in this way gives out a blue glow which is called synchrotron radiation.

synodic period—the time taken by a planet or satellite to return to the same relative positions with respect to the Sun and Earth; hence the average interval between oppositions or conjunctions.

terminator—the line separating the dark and illuminated sides of a planet or satellite. The terminator on the Moon is quite

sharp, indicating the absence of any appreciable atmosphere; the Sun is rising on the terminator before Full Moon, and is setting on this line afterwards.

transit—the passage of any celestial body across the meridian; also used for the passage of a satellite or its shadow across the face of a planet, or of Mercury or Venus across the face of the Sun.

twilight—the illumination of earth and sky which lasts from sunset until darkness, and from darkness until sunrise; there would be no twilight in the absence of an atmosphere, as on the Moon. Theoretically, darkness begins and ends when the Sun is 18° below the horizon, but in this country in the summer months the Sun is not depressed to this extent, and there is a certain amount of twilight throughout the night.

umbra—the central dark part of the shadow of the Moon or of a planet, where no light is received from the Sun; also applied to the darker central region of a sunspot.

U.T.—universal time—see *G.M.T.*

variable stars—stars whose light varies because of some internal cause; the eclipsing binaries are also variable, but are generally treated as a separate class. *See cepheids, cluster-type variables, nova.*

wavelength—the distance between successive troughs or crests in a wave motion; the velocity of the wave is given by frequency multiplied by wavelength. See *angstrom unit.*

white dwarfs—very small faint stars of extraordinarily high density; the normal structure of the atoms in these stars has broken down, and they contain nuclei and electrons packed together as tightly as possible. Their masses are about the same as that of the Sun, but the density may rise to millions of times that of water. Such stars appear to be very common, but are faint and difficult to detect. The best known example is the companion of *Sirius.*

year—the period of the Earth's revolution about the Sun. Measured from equinox to equinox it amounts to 365·2422

days, and the civil calendar, with its rules for leap-years, is designed to allow for the extra decimal of a day.

Zeeman effect—the splitting of a spectrum line into a number of components when the source of light is subject to a strong magnetic field; it is observed in the spectra of sunspots.

zenith—the point on the celestial sphere which is directly overhead, as determined by a plumb-line.

zodiac—a belt of the sky about 8° wide on either side of the ecliptic, in which the Sun, Moon and major planets are always to be found.

zodiacal light—a faint luminous band of light along the ecliptic stretching outwards from the Sun; best seen after sunset or before sunrise. Its spectrum is that of reflected sunlight, and it appears to consist of small particles, forming an extension of the solar corona.

Some Interesting Telescopic Objects

The owner of a small telescope must not expect too much from his instrument. Those wonderful photographs of nebulæ which are used to illustrate text-books are taken with long exposures with large telescopes, and the photographic process can reveal far more than the eye can ever see. However, there is plenty to look for in the sky, and any instrument, however small, will show a great deal of the wonder and beauty of the universe around us.

A telescope is seldom satisfactory for the study of large clusters and groups of stars because the field of view is too small. A pair of binoculars is easier to handle, and will give magnificent views of open clusters such as the Pleiades, the colours of some of the more brilliant stars such as *Betelgeuse* and *Antares*, and the fascinating chains and lines of stars in many parts of the Milky Way, especially in Aquila, Cassiopeia, Cygnus, Lyra and Perseus.

In the following list, which makes no pretence of being complete, some of the more interesting telescopic objects are arranged in order of right ascension. They may all be found on a suitable star atlas, such as *Norton's Star Atlas* (Gall & Inglis), and positions have been given for the benefit of those observers who have telescopes equipped with setting circles.

ALPHA CASSIOPEIÆ (*Shedir*). R.A. $0^h\ 38^m{\cdot}3$, Dec. $+56°\ 20'$

A K-type star in the W. of Cassiopeia. It is an irregular variable, fluctuating between magnitude 2·1 and 2·7, though its normal magnitude is about 2·3. Generally speaking, the variations are very slow, and there is some doubt whether they are real. Beta Cassiopeiæ (magnitude 2·42) is a useful comparison star. The orange hue of *Shedir* is well brought out with binoculars.

MESSIER 31 ANDROMEDÆ. R.A. $0^h\ 40^m{\cdot}6$, Dec. $+41°\ 04'$

The Great Spiral, faintly visible to the naked eye not far from the 4th-magnitude star Nu Andromedæ. It is one of the closest of the external galaxies, and lies at a distance of about 2 million light-years. It must be admitted that in any small or moderate telescope it is a disappointing object, and photographs taken with large instruments are needed to show the spiral form adequately.

H.VIII. 78 CASSIOPEIÆ. R.A. $0^h\ 41^m{\cdot}2$, Dec. $+61°\ 35'$

A fine star-cluster, between Gamma and Kappa Cassiopeiæ. A small telescope will show it well.

GAMMA CASSIOPEIÆ. R.A. $0^h\ 54^m{\cdot}4$, Dec. $+60°\ 31'$

A most extraordinary star, with a spectrum which is classed as B0 (peculiar). It is regarded as a pseudo-nova, since it sometimes undergoes outbursts – for instance in 1936, when it rose to magnitude 1·6. Its normal magnitude is between 2·3 and 2·8. Useful comparison stars are Beta Cassiopeiæ (2·42) and Delta (2·80).

MESSIER 33 TRIANGULI. R.A. $1^h\ 31^m{\cdot}7$, Dec. $+30°\ 28'$

One of the closest of the external galaxies, and a member of the Local Group. Photographs reveal that it is a spiral. In moderate telescopes it is a faint and very difficult object.

GAMMA ARIETIS. R.A. $1^h\ 51^m{\cdot}4$, Dec. $+19°\ 06'$

An excellent double. Magnitudes 4·2, 4·4; position angle 000°; distance $8''{\cdot}4$. Any small telescope will show both components well. It is easy to locate, as it lies close to Beta Arietis.

ALPHA URSÆ MINORIS (*Polaris*). R.A. $1^h\ 57^m{\cdot}2$, Dec. $+89°\ 05'$

The Pole Star. It is of magnitude 2·0, but is actually a cepheid variable of small range. The spectrum is F8. It has a ninth-magnitude companion (p.a. 217°, distance $18''{\cdot}3$) visible with a 3-inch telescope; it is said to be visible even with a 2-inch.

GAMMA ANDROMEDÆ. R.A. $2^h\ 01^m{\cdot}6$, Dec. $+42°\ 09'$

A superb double. The primary is a K-type star of magnitude

2·3; the companion is of magnitude 5, and is bluish (p.a. 061°; distance 9″·7.) The companion is itself a close binary; distance 0″·5, period 55 years. The main pair forms a superb object in a moderate telescope.

H.VI 33–4 PERSEI. R.A. (*for* H.VI. 33) $2^h\ 16^m{\cdot}3$, Dec. +56° 59′

Twin clusters in the 'Sword-Handle' of Perseus; just visible to the naked eye. Each is about 45′ in diameter. Small telescopes will show them adequately; they form one of the most magnificent spectacles in the whole sky. Between the two clusters lies a reddish star.

OMICRON CETI (*Mira*). R.A. $2^h\ 17^m{\cdot}4$, Dec. −3° 09′

The famous variable star. It has an average period of 331 days, and its magnitude range is from 1·6 to 9·6. However, neither the period nor the magnitude range may be regarded as at all constant; at some maxima the magnitude never exceeds 5. The spectrum is of type Me, and the reddish colour makes *Mira* easy to identify.

IOTA CASSIOPEIÆ. R.A. $2^h\ 25^m{\cdot}9$, Dec. +67° 14′

A triple star. Magnitudes 4·2, 7·0, 8·0, p.a's. 251°, 113°; distances 2″·4, 7″.4. Excellently seen with a moderate telescope.

RHO PERSEI. R.A. $3^h\ 02^m{\cdot}7$, Dec. +38° 42′

An M-type irregular variable, not far from *Algol*. The magnitude range is from 3·4 to 4·1; Kappa Persei (4·0) makes a good comparison star. The reddish hue is well brought out in binoculars.

BETA PERSEI (*Algol*). R.A. $3^h\ 05^m{\cdot}7$, Dec. +40° 49′

The 'Demon Star', the prototype eclipsing binary. Its period is 2·87 days. For most of this time it is of magnitude 2·3; it then drops to 3·5 in five hours, and after minimum takes another five hours to climb back to maximum. *Algol* may be studied with the naked eye, and its apparent fluctuations are interesting to follow.

ETA TAURI (*Alcyone*). R.A. $3^h\ 45^m{\cdot}2$, Dec. +23° 59′

The brightest star in the Pleiades (Seven Sisters), the most

conspicuous open cluster in the sky. Keen-sighted persons will be able to see at least eight Pleiads with the naked eye. The best views of the cluster are obtained with binoculars or very low powers on a telescope. The names of the other leading stars in the Pleiades are *Electra*, *Atlas*, *Merope*, *Maia*, *Taygete*, *Celæno*, *Pleione* and *Asterope*.

ALPHA TAURI (*Aldebaran*). R.A. $4^h\ 33^m{\cdot}7$, Dec. $+16°\ 2'6$

A K-type reddish star of magnitude 0·85. It is 57 light-years distant, and is ninety times as luminous as the Sun. Extending from it in a rough V are the stars of the very loose cluster known as the Hyades; one of these (Theta Tauri) is a naked-eye double. *Aldebaran* has a faint companion (magnitude 11; p.a. 034°, distance 121″). Actually, *Aldebaran* is not a true member of the Hyades group, and lies between the cluster and ourselves.

EPSILON AURIGÆ. R.A. $4^h\ 59^m{\cdot}2$, Dec. $+43°\ 46'$

The leading member of the 'Hædi' or Kids, a triangle of three faint stars close to *Capella*. Epsilon is an eclipsing binary; the magnitude range is from 3·3 to 4·1, and the period is over 27 years. One component is a very luminous F-type supergiant. The fainter star is invisible, and appears to be the largest individual star known, with a diameter of over 1,800 million miles.

ZETA AURIGÆ. R.A. $4^h\ 59^m{\cdot}8$, Dec. $+41°\ 01'$

The faintest member of the 'Hædi'. It too is an eclipsing binary, though it is not so vast a system as Epsilon. The spectral types of the components are K0 and B1. The mean magnitude is 4·0; the fluctuations are not easy to detect without instrumental aid.

KAPPA LEPORIS. R.A. $5^h\ 11^m{\cdot}5$, Dec. $-12°\ 59'$

A double star; magnitudes 5·0, 7·5; p.a. 000°; distance $2''{\cdot}6$. The primary is yellowish; the companion bluish.

BETA ORIONIS (*Rigel*). R.A. $5^h\ 12^m{\cdot}7$, Dec. $-8°\ 15'$

The leading star of Orion; magnitude 0·15. The distance is thought to be about 540 light-years. *Rigel* is exceptionally lumin-

ous, and is the equal of at least 18,000 Suns. It has a B-type spectrum, and is almost pure white. There is a seventh-magnitude companion (p.a. 202°, distance 9″·4) easily seen in a 3-inch refractor.

ALPHA AURIGÆ (*Capella*). R.A. 5^h $13^m·9$, Dec. +45° 58′

Magnitude 0·09; spectrum G0. *Capella* is of a yellowish hue, and is a superb object in binoculars. It is an extremely close binary. The distance is 47 light-years, and the luminosity 150 times that of the Sun. Apart from *Arcturus* and *Vega*, it is the brightest star in the northern hemisphere of the sky.

DELTA ORIONIS (*Mintaka*). R.A. 5^h $30^m·1$, Dec. −0° 20′

The upper star of Orion's belt; it lies almost on the celestial equator. The primary is an eclipsing binary of small range; average magnitude 2·4. There is a seventh-magnitude companion (p.a. 000°, distance 52″·8) which is a very easy telescopic object.

MESSIER 1 TAURI. R.A. 5^h $32^m·2$, Dec. + 22° 00′

The 'Crab' Nebula; a fascinating object not far from the third-magnitude star Zeta Tauri. It is the wreck of a supernova which was observed by Chinese astronomers in the year 1054. In a small telescope it appears as a faint, diffuse object; large instruments reveal complex detail. The gas-cloud is still expanding from the old explosion-centre.

MESSIER 42 ORIONIS. R.A. 5^h $33^m·4$, Dec. −5° 25′

In the Sword of Orion; the most prominent gaseous nebula in the sky. It is visible with the naked eye. Excellent views of it are obtained with low powers on small or moderate telescopes. It contains the famous multiple star Theta Orionis, the 'Trapezium' (R.A. 5^h 33^m, Dec. −5° 27′) whose four components are visible in a 3-inch refractor. This superb nebula is always worth looking at.

IOTA ORIONIS. R.A. 5^h $33^m·6$, Dec. −5° 56′

A double star. Magnitudes 3·2, 7·3; p.a. 141°; distance 11″·4. This is the lowest star of Orion's Sword.

SIGMA ORIONIS. R.A. $5^h\ 36^m{\cdot}8$, Dec. $+2°\ 37'$

Another fine multiple in Orion's Sword. Four stars (magnitudes 4, 10, 7·5, 7) are fairly easy to see with a moderate telescope; larger instruments reveal several more.

ZETA ORIONIS. R.A. $5^h\ 38^m{\cdot}8$, Dec. $-1°\ 58'$

The lowest star of Orion's Belt. The 2·0-magnitude, B-type primary has a 5·0-magnitude companion; p.a. 157°, distance $2''{\cdot}8$. This is a well-known test for a 2-inch refractor.

ALPHA ORIONIS (*Betelgeuse*). R.A. $5^h\ 53^m{\cdot}1$, Dec. $+7°\ 24'$

A particularly interesting star. It is an M0-type supergiant, 1,200 times as luminous as the Sun, and 192 light-years away. The diameter is about 250 million miles, but this changes somewhat, as the star is an irregular variable. There is a rough period of about five years. The magnitude range is from 0·1 to 1·3. On very rare occasions *Betelgeuse* has been known to outshine *Rigel*. Its orange-red hue makes it a superb sight in binoculars or a low power.

MESSIER 35 GEMINORUM. R.A. $6^h\ 06^m{\cdot}5$, Dec. $+24°\ 20'$

A splendid open cluster near Mu and Eta Geminorum. This is one of the most spectacular cluster-type objects visible with small telescopes.

ETA GEMINORUM. R.A. $6^h\ 12^m{\cdot}6$, Dec. $+22°\ 31'$

A long-period variable; period 231 days, range 3·3 to 4·2. The spectrum is of type M, and the colour orange-red. The neighbouring star Mu, magnitude 3·2 and also of type M, makes a good comparison. The variations of Eta are slow, but may be followed with the naked eye.

BETA MONOCEROTIS. R.A. $6^h\ 27^m{\cdot}0$, Dec. $-7°\ 00'$

A triple star. Magnitudes 5·0, 5·5, 6·0; p.a. 132°, 105°, distances $7''{\cdot}4$, $2''{\cdot}8$. A fine sight in a moderate telescope.

H.VII. 2 MONOCEROTIS. R.A. $6^h\ 30^m{\cdot}3$, Dec. $+4°\ 54'$

A beautiful open cluster just visible to the naked eye.

ALPHA CANIS MAJORIS (*Sirius*). R.A. $6^h\ 43^m{\cdot}5$, Dec. $-16°\ 40'$

The brightest star in the sky. It is of magnitude $-1{\cdot}43$, and has an A0-type spectrum; it is 26 times as luminous as the Sun, and is one of the closest of all stars, since its distance is only 8·6 light-years. It is a wonderful sight in binoculars. The famous companion, Sirius B, is a white dwarf, but unfortunately invisible except in large telescopes.

MESSIER 41 CANIS MAJORIS. R.A. $6^h\ 45^m{\cdot}4$, Dec. $-20°\ 42'$

An open cluster, just visible to the naked eye and excellently seen with low powers.

ZETA GEMINORUM. R.A. $7^h\ 01^m{\cdot}9$, Dec. $+20°\ 38'$

A cepheid variable. Its magnitude range is from 3·7 to 4·3, and its period is 10·2 days. Nu Geminorum (magnitude 4·1) is a useful comparison star. Zeta has a G-type spectrum, and is rather yellowish.

ALPHA GEMINORUM (*Castor*). R.A. $7^h\ 32^m{\cdot}2$, Dec. $+31°\ 58'$

The senior though fainter of the famous 'Twins'. It was ranked of the first magnitude by the old astronomers, but is now appreciably below; its magnitude is 1·6. It is a fine binary, with a period of 350 years; p.a. 204°, distance 4″. The individual magnitudes of the two components are 2·0 and 2·8. Each is a spectroscopic binary, and the faint eclipsing binary YY Geminorum (=Castor C) is also a member of the system.

BETA GEMINORUM (*Pollux*). R.A. $7^h\ 43^m{\cdot}0$, Dec. $+28°\ 07'$

The orange hue of *Pollux* (spectrum K0) contrasts with the pure white of *Castor*. The magnitude is 1·2, the distance 32 light-years, and the luminosity 28 times that of the Sun.

MESSIER 44 CANCRI. R.A. $8^h\ 38^m$, Dec. $+20°\ 07'$

Præsepe, or the 'Beehive', is a fine open cluster. It is easily

visible to the naked eye on a moonless night, close to the two faint stars Delta and Gamma Cancri. It is well seen with low powers, and is not difficult to resolve into separate stars.

ALPHA HYDRÆ (*Alphard*). R.A. $9^h\ 25^m{\cdot}7$, Dec. $-8°\ 30'$

Alphard, the 'Solitary One', is easy to locate; it lies more or less in line with *Castor* and *Pollux*, and is very isolated. Moreover it is of type K, and decidedly red. *Alphard* is a spectacular object when viewed with binoculars.

GAMMA LEONIS. R.A. $10^h\ 17^m{\cdot}9$, Dec. $+20°\ 02'$

A binary with a period of 407 years. The magnitudes are 2·4 and 3·8; the p.a. 119°, and the distance 4″. The star is easy to identify, as it lies in the famous Sickle of Leo, not far from *Regulus*. It is a fine sight in a moderate telescope.

U HYDRÆ. R.A. $10^h\ 35^m{\cdot}7$, Dec. $-13°\ 11'$

An N-type irregular variable, with a range from magnitude 4·5 to 6. It is the brightest of the stars of spectrum N, and its deep-red colour makes it of great interest.

MESSIER 97 URSÆ MAJORIS. R.A. $11^h\ 12^m{\cdot}6$, Dec. $+55°\ 13'$

The 'Owl' nebula. It is 3′ in diameter, and is one of the interesting objects known as planetary nebulæ. It is not, however, very conspicuous, and will hardly be seen in a small telescope.

GAMMA VIRGINIS. R.A. $12^h\ 39^m{\cdot}7$, Dec. $-1°\ 14'$

One of the most spectacular binaries in the sky. Each component is of type F0, and the magnitudes are almost equal at 3·6. The period is 180 years, and the separation is becoming steadily less, but it is still well over 5″, so that the components are excellently seen in a small telescope.

ALPHA CANUM VENATICORUM (*Cor Caroli*). R.A. $12^h\ 54^m{\cdot}3$, Dec. $+38°\ 31'$

An easy double. Magnitudes 3·1, 5·6; p.a. 228°; distance 19″·7.

ZETA URSÆ MAJORIS (*Mizar*). R.A. $13^h\ 22^m{\cdot}4$, Dec. $+55°\ 07'$

The second star in the Plough-handle. It forms a naked eye pair with *Alcor* (magnitude 5). *Mizar* is itself a binary; magnitudes 2·2, 4·2; p.a. 150°, distance 14″·5. In any small telescope the components are easily separated. With low powers *Alcor* also is in the field, and between it and *Mizar* is yet another star. This is one of the best binary objects for small apertures, particularly as *Mizar* is so easy to locate.

MESSIER 3 CANUM VENATICORUM. R.A. $13^h\ 40^m{\cdot}4$, Dec. $+28°\ 34'$

A bright globular cluster on the borders of Canes Venatici and Boötes. With a moderate telescope, the cluster is fully resolvable into stars.

ALPHA BOÖTIS (*Arcturus*). R.A. $14^h\ 13^m{\cdot}9$, Dec. $+19°\ 23'$

Apart from *Sirius*, *Arcturus* is the brightest star visible from the latitude of Britain. Its magnitude is −0·06, its distance 41 light-years, and its luminosity 100 times that of the Sun. The spectrum is of type K, and *Arcturus*' glorious orange hue makes it a fine sight with binoculars or a low power.

EPSILON BOÖTIS. R.A. $14^h\ 43^m{\cdot}3$, Dec. $+27°\ 14'$

A third-magnitude star with a sixth-magnitude companion at distance 2″·8, p.a. 335°. The primary is yellowish, the companion bluish.

R CORONÆ BOREALIS. R.A. $15^h\ 47^m{\cdot}0$, Dec. $+28°\ 16'$

A curious irregular variable. For long periods the magnitude remains at 6, and then drops suddenly, sometimes to below 12. After a period of minimum brilliancy, which may be protracted, the star rises once more to magnitude 6. The causes of this behaviour are unknown, and amateur observers can do valuable work by studying R Coronæ and other stars of its type.

T CORONÆ BOREALIS. R.A. $15^h\ 57^m{\cdot}9$, Dec. $+26°\ 02'$

The 'Blaze Star'. Normally it is of below magnitude 8, but it has

suffered two major outbursts – one in 1866 (magnitude 2) and the other in 1946 (magnitude 4). Minor fluctuations are always going on, and the star merits close attention from amateur observers.

BETA SCORPIONIS. R.A. $16^h\ 03^m{\cdot}2$, Dec. $-19°\ 42'$

Magnitudes 3·0, 5·2; p.a. 023°; distance 14″. This is a wide, easy double.

MESSIER 80 SCORPIONIS. R.A. $16^h\ 14^m{\cdot}8$, Dec. $-22°\ 53'$

A bright globular cluster between *Antares* and Beta Scorpionis. Well seen in a moderate telescope.

MESSIER 4 SCORPIONIS. R.A. $16^h\ 21^m{\cdot}3$, Dec. $+26°\ 26'$

An open cluster, close to *Antares*. The diameter is about 14′, and the whole cluster is easily resolvable.

ETA DRACONIS. R.A. $16^h\ 23^m{\cdot}5$, Dec. $+61°\ 36'$

A G5-type star of magnitude 2·9, with an eighth-magnitude companion at p.a. 142°, distance 6″·1. It is a test for a 3-inch refractor.

ALPHA SCORPIONIS (*Antares*). R.A. $16^h\ 27^m{\cdot}1$. Dec. $-26°\ 21'$

The 'Rival of Mars'. *Antares* is an M-type supergiant, 3,400 times as luminous as the Sun, and 360 light-years away. It is strongly red in hue, and has a seventh-magnitude greenish companion at p.a. 275°, distance 3″. For some time *Antares* was believed to be the largest star known; though it is in fact surpassed by others, it is still of exceptional size. It is unfortunate that it never rises very high over the British horizon.

ZETA HERCULIS. R.A. $16^h\ 39^m{\cdot}9$, Dec. $+31°\ 40'$

A splendid binary with a period of 34 years. The distance reached 1″·6 in 1954, and is now decreasing. The primary is a star of spectral type G0, magnitude 3; the companion is of magnitude 6·5.

MESSIER 13 HERCULIS. R.A. $16^h\ 40^m$, Dec. $+36°\ 32'$

The brightest of the globular clusters visible from the latitude

of Britain. It may be seen with the naked eye on a clear night, and lies between Zeta and Eta Herculis, considerably closer to Eta. With a moderate telescope, it is fully resolvable, and is a magnificent sight, but in very small instruments it is somewhat disappointing.

ALPHA HERCULIS. R.A. $17^h\ 12^m{\cdot}9$, Dec. $+14°\ 26'$

One of the most interesting stars in the sky. The primary is an M-type supergiant, variable between magnitudes 3 and 3·7 in an irregular manner; it has the distinction of being one of the largest stars known. The companion (magnitude 6, p.a. 112°, distance $4''{\cdot}5$) is distinctly green. In a moderate telescope the colours make a superb contrast. The fluctuations of the primary may be followed with the naked eye; Kappa Ophiuchi (magnitude 3·4) makes a useful comparison star.

MESSIER 92 HERCULIS. R.A. $17^h\ 16^m{\cdot}0$, Dec. $+43°\ 11'$

A globular cluster between Eta and Iota Herculis. It resembles M13, but is much less conspicuous.

MESSIER 7 SCORPIONIS. R.A. $17^h\ 51^m{\cdot}5$, Dec. $-34°\ 49'$

A magnificent open cluster near the Scorpion's 'sting'. Unfortunately it is never well seen in Britain, as it is always low in the sky.

MESSIER 23 SAGITTARII. R.A. $17^h\ 54^m{\cdot}7$, Dec. $-19°\ 01'$

An open cluster almost 50′ in diameter, well seen with a low power.

H.IV. 37 DRACONIS. R.A. $17^h\ 58^m{\cdot}6$, Dec. $+66°\ 38'$

One of the brightest of the planetary nebulæ. It is well seen with a moderate telescope.

MESSIER 8 SAGITTARII. R.A. $18^h\ 01^m{\cdot}3$, Dec. $-24°\ 23'$

The 'Lagoon' nebula. This is a gaseous nebula, and is contained in our own Galaxy. It is faintly visible with the naked eye, and moderate telescopes show a large amount of detail; there are

bright patches and dark rifts. This whole area is rich in nebular objects, and is well worth sweeping.

N.G.C. 6572 OPHIUCHI. R.A. $18^h\ 10^m{\cdot}2$, Dec $+6°\ 50'$

A small, bright planetary nebula, lying between Beta Ophiuchi and Zeta Aquilæ. It is an easy object in a small telescope.

MESSIER 17 SAGITTARII. R.A. $18^h\ 18^m{\cdot}6$, Dec. $-16°\ 12'$

The 'Omega' nebula. The nearest naked-eye star is Gamma Scuti. Like the Lagoon, this is a gaseous nebula contained in our own Galaxy, and is large and bright, with abundant detail.

ALPHÆ LYRÆ (*Vega*). R.A. $18^h\ 35^m{\cdot}7$, Dec. $+38°\ 45'$

Vega is the brightest star in the northern hemisphere of the sky, apart from *Arcturus*. Its magnitude is 0·0, its spectral type A0, its distance 26 light-years and its luminosity 50 times that of the Sun. It is notable because of the distinctly bluish cast which makes it a superb object in low powers. It has a companion of magnitude 10·5, at p.a. 170°, distance 56″. This is an optical pair, and not a binary; the companion is faint and moreover overpowered by the brilliance of the primary, so that it is not a particularly easy object. *Vega* is very high up during summer evenings, and cannot be mistaken.

EPSILON LYRÆ. R.A. $18^h\ 43^m{\cdot}1$, Dec. $+39°\ 34'$

A fascinating quadruple star. Epsilon^1 and Epsilon^2 form a naked-eye pair (distance 208″), and are easy to find, since they lie near *Vega*. Each is again double; Epsilon^1 (magnitudes 4·6, 6·3; p.a. 005°; distance 3″) and Epsilon^2 (4·9, 5·2; 111°; 2″·3) and there are various other stars in the same low-power field. This is a particularly good object for viewing with a small or moderate telescope.

ZETA LYRÆ. R.A. $18^h\ 43^m{\cdot}5$, Dec. $+37°\ 34'$

A wide, easy double. Magnitudes 4·2, 5·5; p.a. 150°; distance 44″.

BETA LYRÆ. R.A. $18^h\ 48^m{\cdot}7$, Dec. $+33°\ 19'$

The prototype 'ellipsoidal' variable. It is not in fact a true

variable, but is an eclipsing binary of special type. The maximum is magnitude 3·4; the minima are alternately of magnitude 3·8 and 4·1; the period is 12·9 days. Gamma Lyræ (magnitude 3·3) is a useful comparison star. The system of Beta Lyræ is of particular interest from an astrophysical point of view. The spectra are B8 and B2, but each is peculiar, and the components are too close to be separated visually.

MESSIER 11 SCUTI. R.A. $18^h\ 49^m{\cdot}0$, Dec. $-6°\ 19'$

The 'Wild Duck'. A superb open cluster, not far from Lambda Aquilæ. It is faintly visible to the naked eye. A moderate telescope shows it as a fan-shaped cluster, with a bright star at its apex.

MESSIER 57 LYRÆ. R.A. $18^h\ 52^m{\cdot}2$, Dec. $+32°\ 49'$

The 'Ring' nebula. This is the most famous of the nebulæ, and is extremely easy to find, as it lies between Beta and Gamma Lyræ. In a small telescope it does indeed look like a ring; the dark centre is easy to see, but the central star is a difficult object.

THETA SERPENTIS. R.A. $18^h\ 54^m{\cdot}3$, Dec. $+4°\ 09'$

One of the best double stars for a small telescope. The components are almost equal at magnitude 4·1; the p.a. is 103°, and the distance $22''{\cdot}3$. The star is easy to find, as it lies almost in a line with Theta, Eta and Delta Aquilæ. Each component is white.

BETA CYGNI. R.A. $19^h\ 29^m{\cdot}2$, Dec. $+27°\ 53'$

Beta Cygni (*Albireo*) is probably the loveliest double star in the sky. It is an easy object; the magnitudes are 3·0 and 5·3, the p.a. 055°, and the separation $35''$, so that any small telescope will show it. The contrasting colours make it striking; the primary is yellow, while the companion is strongly bluish-green. *Albireo* appears the faintest of the five stars which make up the cross of Cygnus, but it is in fact a very luminous star lying at a great distance from us.

CHI CYGNI. R.A. $19^h\ 49^m{\cdot}1$, Dec. $+32°\ 49'$

An M-type long-period variable. The range is from magnitude

4 to 14, and the period 409 days; it is the *Mira* type. When near maximum it is easily visible to the naked eye, and may be compared with its near neighbour Eta Cygni (magnitude 4). Near minimum, a powerful telescope is needed to show it.

ETA AQUILÆ. R.A. $19^h\ 50^m{\cdot}5$, Dec. $+0°\ 54'$

Spectrum G0 (peculiar). Eta is a typical cepheid variable, with a range from magnitude 3·7 to 4·5, and a period of 7·18 days. It lies between Delta (magnitude 3·4) and Theta (also 3·4), which are useful as comparison stars.

MESSIER 27 VULPECULÆ. R.A. $19^h\ 57^m{\cdot}9$, Dec. $+22°\ 37'$

The curious galactic 'Dumb-bell' nebula, not far from Gamma Sagittæ. It is a faint object in a small telescope, but is well worth looking for.

ALPHA CAPRICORNI. R.A. $20^h\ 15^m{\cdot}7$, Dec. $-12°\ 39'$

A naked-eye double; Alpha^1 and Alpha^2, of magnitudes 3·7 and 4·3 respectively, are separated by 378″. Alpha^1 has a ninth-magnitude companion at 45″. Alpha^2 is itself a difficult double; the companion is of magnitude 11, position angle 158°, distance 7″. Since the faint companion is a close binary, the whole system is decidedly complex.

ALPHA CYGNI (*Deneb*). R.A. $20^h\ 40^m{\cdot}1$, Dec. $+45°\ 09'$

The brightest star of Cygnus. It is of magnitude 1·3, and has a peculiar A2-type spectrum. It is an exceptionally luminous star, at least 10,000 times as brilliant as the Sun, and is of great interest to astrophysicists. Its yellowish colour is well shown by use of a low power.

GAMMA DELPHINI. R.A. $20^h\ 44^m{\cdot}9$, Dec. $+15°\ 29'$

A wide, easy double. Magnitudes 4, 5; p.a. 270°, distance 10″·4. The primary is yellowish, the companion greenish.

H.IV. 1 AQUARII. R.A. $21^h\ 02^m{\cdot}1$, Dec. $-11°\ 31'$

A bright planetary nebula, known as the Saturn nebula for

reasons which will be obvious when the object is studied with a large aperture. In smaller telescopes the Saturn-like appearance is not seen, but nevertheless the nebula is a most interesting object. It lies near the fourth-magnitude star Nu Aquarii.

61 CYGNI. R.A. $21^h\ 05^m{\cdot}2$, Dec. $+38°\ 33'$

An easy binary; magnitudes 5·3, 5·9; p.a. 134°; distance 25″. 61 Cygni is famous as being the first star to have its distance measured – by Bessel, in 1838. The system is about 11 light-years away. Both components are dwarfs, and the fainter (B) is suspected to have a large planet associated with it.

MESSIER 15 PEGASI. R.A. $21^h\ 28^m{\cdot}1$, Dec. $+12°\ 00'$

A splendid globular cluster not far from Epsilon Pegasi (magnitude 2·5). A small telescope will show it well.

BETA CEPHEI. R.A. $21^h\ 28^m{\cdot}2$, Dec. $+70°\ 24'$

A third-magnitude star with an eighth-magnitude companion at p.a. 250°, distance 13″·7. As it is circumpolar, it makes a useful test (for small apertures) which is available on any clear night.

MESSIER 39 CYGNI. R.A. $21^h\ 30^m{\cdot}9$, Dec. $+48°\ 16'$

A large open cluster, between *Deneb* and Alpha Lacertæ, well seen with low powers.

MU CEPHEI. R.A. $21^h\ 42^m{\cdot}3$, Dec. $+58°\ 36'$

The 'Garnet Star' of Sir William Herschel. It is a *Betelgeuse* type irregular variable, but since its fluctuations lie between magnitudes 4 and 6 it is never brilliant. However, any optical aid will bring out its lovely red colour; it has been compared with a glowing coal.

DELTA CEPHEI. R.A. $22^h\ 27^m{\cdot}8$, Dec. $+58°\ 13'$

The prototype cepheid. It changes between magnitudes 3·7 and 4·3 in a period of 5·37 days. Its neighbour Zeta (magnitude 3·6) makes a useful comparison star.

ALPHA PISCIS AUSTRINI (*Fomalhaut*). R.A. $22^h\ 55^m.6$, Dec. $-29°\ 49'$

This is the southernmost of the first-magnitude stars visible from Britain. It can be quite conspicuous from southern England, but from northern Scotland it is always extremely low down. It is of spectrum A3, and is 13 times as luminous as the Sun. As it lies at a distance of only 24 light-years, it is the nearest of the first-magnitude stars apart from *Sirius*, *Procyon* and *Alpha Centauri*.

BETA PEGASI. R.A. $23^h\ 01^m.9$, Dec. $+27°\ 53'$

An M-type variable of the *Betelgeuse* class. Its range is between magnitudes 2·3 and 2·8, and there is a very rough period of about five weeks. It is one of the stars making up the Square of Pegasus, and good comparisons are Alpha Pegasi (2·6) and Gamma (2·9). Beta is strongly orange in hue, and its alterations in brightness may be followed with the naked eye. Incidentally, it is instructive to select a clear night and then count the number of naked-eye stars contained in the Square of Pegasus. There are not very many of them!

Biographical Notes on Contributors

DR J. G. PORTER was for many years concerned with the production of the *Nautical Almanac*, and retired from the Royal Greenwich Observatory in 1961; between 1961 and 1962 he was carrying out research in the United States. In addition to his computing work, he has specialized in the study of comets and meteors, and is the author of *Comets and Meteor Streams*. He is a Past President of the British Astronomical Association, and a former Director of its Computing Section. For over ten years he made monthly broadcasts on astronomical subjects.

PATRICK MOORE is an amateur astronomer who has written several books and made regular broadcasts. He is Director of the Mercury and Venus Section of the British Astronomical Association.

H. E. DALL has an international reputation as an expert upon astronomical instrumentation of all types, and has made many original contributions during the past thirty years. He is a Member of Council of the British Astronomical Association. He lives at Luton, and carries out astronomical observations (largely photographic) from his private observatory with equipment constructed by himself.

DR GERARD DE VAUCOULEURS carried out research for some years in France, and subsequently in the Commonwealth Observatory in Australia; he is now Professor of Astronomy at the University of Texas. In addition to his extremely important work in connexion with astrophysics, he has made a special study of Mars, and his work *Physics of the Planet Mars* is accepted as the standard.

W. M. BAXTER, Secretary of the British Astronomical Association, is an amateur astronomer. For many years he took a

general interest in the subject; upon his retirement from business he decided to use his observatory for studying the Sun, and has achieved a wide reputation in this field. He is also a skilled photographer – both terrestrial and astronomical. His book about the Sun is due for publication early in 1963.

DR R. F. GRIFFIN is an astrophysicist on the staff of the Cambridge Observatories, and is a Research Fellow of St John's College, Cambridge. He has also held a post-doctoral Fellowship at the Mount Wilson and Palomar Observatories.

DR MAX H. HEY was born in 1904 at Leyland, Lancashire; he was educated at Manchester Grammar School and Magdalen College, Oxford. He is a mineral analyst and crystallographer at the Department of Mineralogy, British Museum (Natural History). He lists his recreations as Scouting, Chopin, and Carrollian nonsense.

HENRY BRINTON is the author of numerous political works, as well as novels. He is also known as a children's science writer, and is a frequent broadcaster on sound and television. His private observatory at Selsey, in Sussex, is equipped with a $12\frac{1}{2}$-inch optical reflector as well as a home-made radio telescope. He was elected to the Council of the British Astronomical Association in 1962.

PAUL MURDIN has been interested in astronomy from an early age, and was elected secretary of the Radio and Electronics Section of the British Astronomical Association while still a student. He is at present at Wadham College, Oxford. He is co-author of a children's book about telescopes, and has made several television broadcasts in connexion with astronomy.

E. A. BEET, Senior Science Master at the Royal Nautical College, Pangbourne (Reading), is well known as an educationalist in astronomy, and his books have done much to encourage young enthusiasts. After serving ten years as Secretary of the British Astronomical Association, he was elected President for the session 1962–3.

Yearbook of Astronomy 1963

Edited by J. G. Porter Associate Editor Patrick Moore

This Yearbook for the amateur astronomer began with the 1962 edition last year. Two comments in the press show how it was welcomed:

Nature: 'It succeeds admirably . . . we look forward to seeing the Yearbook maintaining the high standard of this issue for many years to come . . . a very useful addition to the shelves of any amateur astronomer.'

The Observer: 'The first publication I have come across which makes it easy for the amateur to follow the movements of stars and planets throughout the year without being initiated into the mysteries of tables of ephemerides and other complexities. An ingenious system of charts makes it simple to find the position of any constellation or planet at any time, or to identify particular stars.'

The 1963 edition follows the same successful pattern. It contains star charts and data to help the amateur find his way about the sky, notes on the planets and other interesting telescopic objects, and a series of articles on various subjects, including a review of important astronomical advances during the past year. There is a list of societies that the amateur can join and various other useful pieces of information.

Once again this Yearbook will be of outstanding interest and usefulness to all amateur astronomers.

The picture on the cover shows Henry Brinton's run-off observatory at Selsey. The telescope is a 12½ in reflector. This is the observatory described in the article on page 137.

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